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Final Report

ESTIMATING STATEWIDE TRIP TABLES FROM VEHICLE CLASSIFICATION COUNTS

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PURDUE UNIVERSITY

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16. Abstract

Although a statewide trip table is an important ingredient in the statewide planning process, such information is difficult to obtain. The study described in this report investigated the applicability to the state-level problem of existing software developed to estimate trip tables in urban areas (or smaller) from link counts. Criteria that would form the basis for determining the applicability of any particular software package were developed. Packages such as The Highway Emulator (THE), PC-LINKOD, and Fast Matrix Calibration (FMC) were tested using small and medium sized networks.

Because FMC performed the best on these tests, it was applied to the state-level trip table estimation problem. However, FMC was designed to update an existing trip table, and Indiana had no such previous trip table. As a result, an "O-D Factoring" procedure was adopted to convert zone-by-zone origin and destination totals into an initial trip table that could be updated by FMC. By making some adjustments to the elasticities in FMC, a trip table was developed for the Indiana state highway network.

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CHAPTER 1 INTRODUCTION

The Origin-Destination (O-D) matrix plays an important role in transportation planning. Some common applications are to observe the flow of traffic between zones, to establish detours around major construction sites or accident locations, to calculate vehicle miles traveled and related taxes, and IVHS applications [Fricker, 1991].

Traditional methods of obtaining Origin-Destination tables are time consuming and labor intensive, which translates to high cost, in terms of both labor and capital. The methods may involve home interviews, roadside sampling, and license plate surveys. Surveys are time consuming and intrusive to the subject. In addition, the degree of accuracy is questionable, because people may not answer sensitive questions honestly. Interview results are often unreliable and become outdated rather quickly.

The idea of using link counts as the only input data is very attractive because these data are already available at no additional cost to the Indiana Department of Transportation (INDOT). Link count information for Indiana roads is contained in the publication *Highway Traffic Statistics* that is updated annually [INDOT, 1991 et seq.]. The Roadway Management Division of INDOT is responsible for the compilation of this report. Average annual daily traffic (AADT) values are organized by county, with the data in each county are updated at least every four years, so that the traffic count data are up-to-date.

Most research on O-D matrix calculation has been directed at small geographic areas, such as urban or metropolitan networks. This project deals with a statewide network, more precisely, the network of major highways in Indiana. Many O-D packages require an initial target or seed trip table, but no previously developed trip table for Indiana exists. This project will establish the effects and results of using a variety of artificial trip tables in lieu of an actual historically-based initial trip table. Various initial O-D matrices will be tested and have their value in synthesizing trip tables determined.

This project also serves as a mini-user guide to practitioners thinking about implementing one or more packages in the near future. The report consists of two main parts: evaluation and implementation. The first part of the report will include results various of tests with three PC computer packages and make a software recommendation. The second part of the study will discuss the model chosen for Indiana and issues related to preparing files for the model.

1.1 Test Networks

Two test networks will be used in this study to assist the evaluation of the candidate computer programs. The Gur 730 network, consisting of 6 zones, 12 nodes, and 18 one-way links, is an artificial network and is used to gain initial knowledge on how each O-D estimation software package operates. The second network, the Village network, has 15 zones, 63 nodes, and 166 one-way links. The Village network is an actual network in an area near Purdue University; it has traffic and O-D information that are valuable in comparing the software packages.

1.2.1 Gur 730 Network

Mark Turnquist and Yehuda Gur created the network shown in Figure 1.1 [Turnquist and Gur, 1979]. The test network is much the same as the original, except for a few minor changes and assumptions to accommodate certain software requirements. First, the node numbers have been changed because of THE's sequential node numbering requirement. Node 13 is added because there cannot be connectors directly between two zones. In addition, zones 5 and 6 are switched to conform with some other tests performed on this network. All links are 7 miles in length, except for the path 5-13-6, where the total length is 7 miles. The capacity on each link is defined by the BPR link performance function:

$$\text{travel\_time} = \text{free\_flow\_time} \times \left(1 + 0.15 \times \left(\frac{\text{observed\_volume}}{0.75 \times \text{capacity}}\right)^4\right)$$

The term (0.75 * capacity) conforms to the standard UTPS program UROAD's definition of Level of Service C capacity as 75% of the Level of Service E capacity [Beagan, 1991a]. Backsolving for the capacity, on link 5-8, for example, given an observed time of 10 minutes, a free flow time of 7 minutes, and observed volume of 500 vehicles, leads to a capacity of 512.

According to Daniel Beagan of the Central Transportation Planning Staff (CTPS), this network can be solved algebraically with assumptions on link use probabilities [Beagan, 1991a]. Link use probability ranges between 0 and 1; they indicate the usage of each path by an O-D pair. In this network there are three sets of O-D pairs for which there are two paths available. From zone 5 to 6, there are paths 5-8-10-6 and 5-13-6. Between zones 4 and 3, there are paths 4-9-10-12-3 and 4-9-11-12-3. And for zones 6 and 2, there are paths 6-10-9-11-2 and 6-10-12-11-2. Three link use probabilities are used: Z designates percentage use of the path 5-13-6, Y designates the use of 6-10-12-11-2, and X designates the use of 4-9-11-12-3. Beagan assumed the link use proportions of Z = 0.5, Y = 1 and X = 1. The calculations are done using TK Solver. The algebraic equations are shown in Table 1.1. The results with Beagan's assumptions are seen in Table 1.2. Prefix V designates volume on the link and T stands for the trips between zones. The number following the prefix is a node or zone number. For example, V58 is the volume on the link from node 5 to node 8, and T46 is the number of trips that went from zone 4 to zone 6. The solution in Table 1.2 is not a unique solution; two other solutions are shown in Table 1.3 and 1.4 with different link use probabilities as calculated by TK Solver. There is a variation of loading that depends on assumed link use proportions. The O-D table that resulted from Beagan's assumption is shown in Table 1.5.

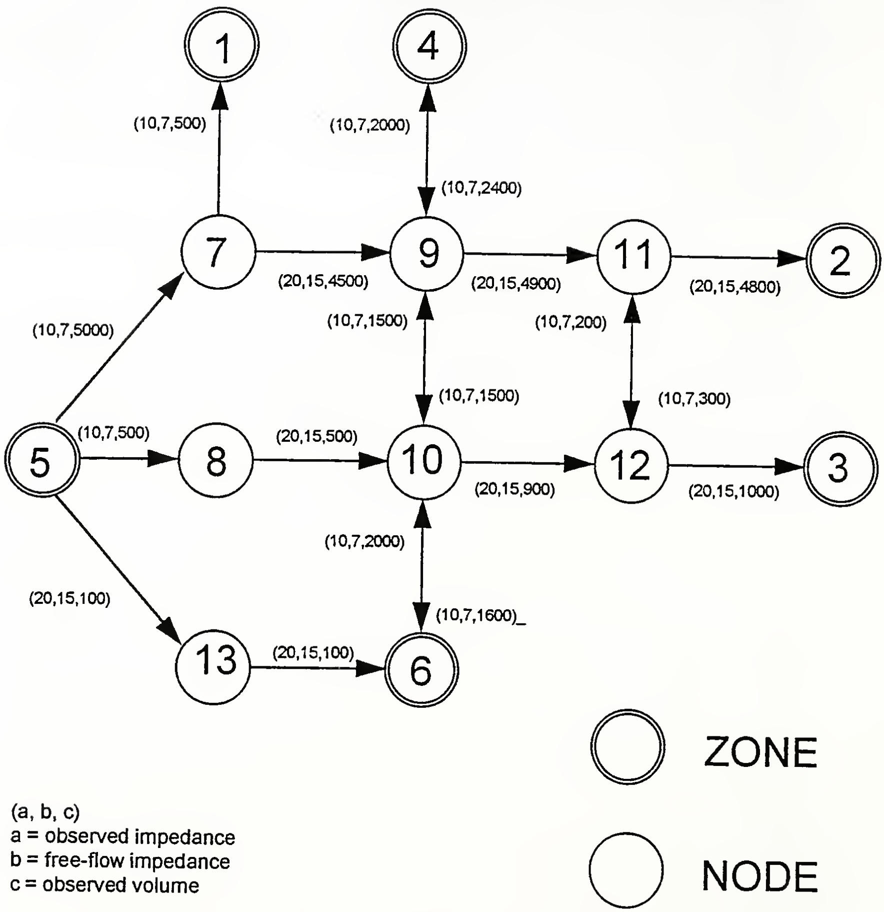

Figure 1.1 Gur 730 Network

Table 1.1 Beagan's Equations

```
V57    = T51+T52+T54
V58    = T53+(1-Z)*T56
V513   = Z*T56
V71    = T51
V79    = T52+T54
V810   = T53+(1-Z)*T56
V49    = T42+T43+T46
V94    = T54+T64
V910   = (1-X)*T43+T46
V109   = (1-Y)*T62+T64
V106   = T46+(1-Z)*T56
V610   = T62+T63+T64
V911   = T42+X*T43+(1-Y)*T62+T52
V1012  = (1-X)*T43+T53+Y*T62+T63
V1112  = X*T43
V1211  = Y*T62
V11_2  = T42+T52+T62
V12_3  = T43+T53+T63
```

Table 1.2 Link Use Probabilities According to Beagan

Link Use Probability	O-D Pair	Trip Value
	T51	500
	T52	4000
	T54	500
	T53	400
.5	Z	
	T56	200
	T42	600
	T43	300
	T46	1500
	T64	1500
1	X	
1	Y	
	T62	200
	T63	300

Table 1.3 Solution I for Gur 730 Network

Link Use Probability	O-D Pair	Trip Value
	T51	500
	T52	2802.1244
	T54	1697.8756
	T53	189.24263
.24345272	Z	
	T56	410.75737
	T42	599.99999
	T43	510.75738
	T46	1289.2426
	T64	302.12442
.58736302	X	
.14307425	Y	
	T62	1397.8756
	T63	299.99999

Table 1.4 Solution II for Gur 730 Network

Link Use Probability	O-D Pair	Trip Value
	T51	500
	T52	2824.6202
	T54	1675.3798
	T53	111.49496
.20470618	Z	
	T56	488.50504
	T42	600
	T43	588.50504
	T46	1211.495
	T64	324.62021
.50976624	X	
.14541438	Y	
	T62	1375.3798
	T63	300

Table 1.5 Beagan's Trip Table

FROM/TO	1	2	3	4	5	6	TOTAL
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0
4	0	600	300	0	0	1500	2400
5	500	4000	400	500	0	200	5600
6	0	200	300	1500	0	0	2000
TOTAL	500	4800	1000	2000	0	1700	**10000**

1.2.2 Village Network

A significant step up from the Gur 730 network in terms of size, complexity, and reality is the Village network. The network is an actual street system near Purdue University's campus before a major change of street orientation; the change took place in May 1991, altering many streets from two-way to one-way operation. O-D and link loading information is available, which makes this network an excellent test network. In addition, this network has heavy through traffic, which is similar to the situation in the Indiana network. The Village network is shown in Figure 1.2. The O-D table for the network, obtained from a license plate survey, is shown in Table 1.6.

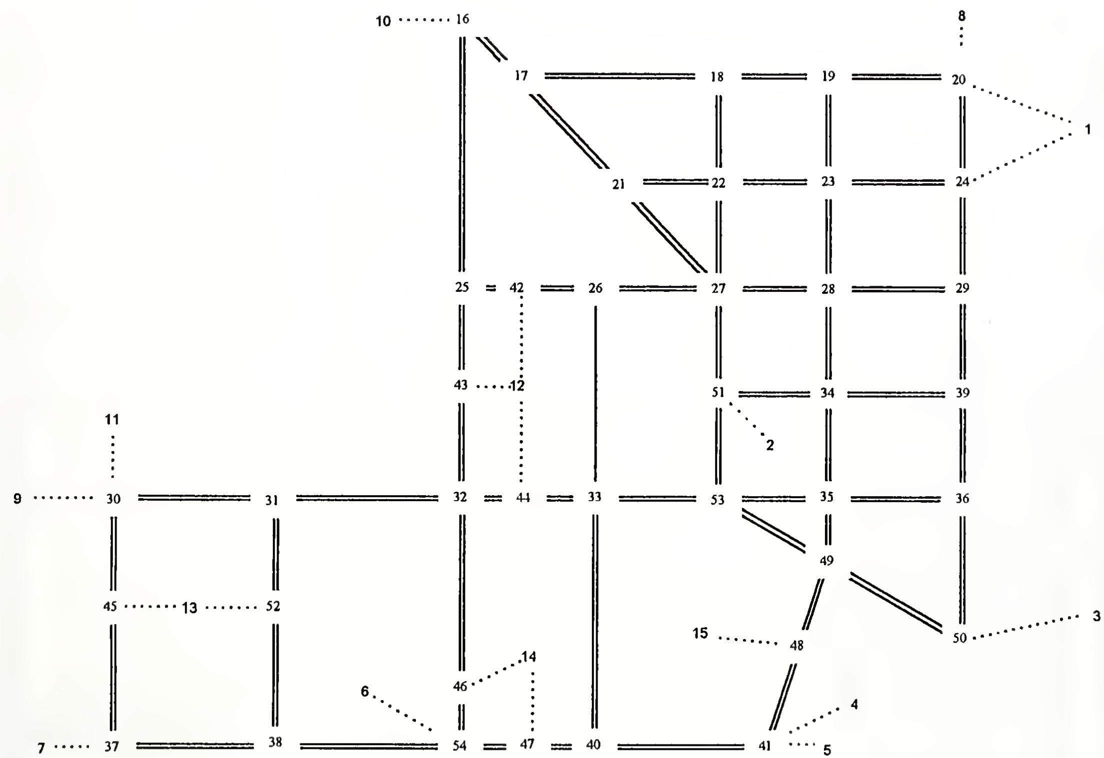

Figure 1.2 Village Network

Table 1.6 Village Observed O-D Matrix

FROM/TO	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	TOTAL
1	0	14	96	39	24	17	11	65	105	396	22	24	4	13	34	864
2	26	0	24	2	1	1	0	3	49	34	2	1	0	1	8	152
3	75	2	0	29	17	12	9	49	247	186	30	16	3	10	26	711
4	35	0	32	0	4	2	2	9	27	50	4	4	0	2	5	176
5	55	1	51	10	0	4	2	15	43	79	6	6	0	4	8	284
6	58	1	51	10	6	0	2	15	44	82	6	6	0	4	8	293
7	59	1	54	10	6	4	0	15	46	84	6	6	0	4	8	303
8	58	1	53	9	6	4	2	0	45	83	6	6	0	4	8	285
9	146	33	293	55	32	23	15	90	0	184	44	31	4	20	36	1006
10	670	26	219	69	41	28	21	113	143	0	45	40	7	24	96	1542
11	20	0	19	4	2	2	0	6	16	29	0	2	0	0	3	103
12	50	5	34	7	3	3	2	12	37	82	4	0	0	2	13	254
13	31	6	64	8	4	4	2	14	41	59	7	4	0	2	7	253
14	51	2	60	6	3	3	1	10	26	66	0	3	0	0	27	258
15	33	0	30	6	2	2	2	9	27	48	4	2	0	2	0	167
TOTAL	1367	92	1080	264	151	109	71	425	896	1462	186	151	18	92	287	6651

1.2.3 Initial Trip Tables

Part of the input data for the O-D software packages is an initial trip table. This prior information serves as a starting point for the O-D estimation calculation. In general, the initial trip table, or seed table, contains outdated O-D information about the network. In lieu of an old seed table, other trip tables may be used. For the two test networks, three types of initial trip tables will be used and evaluated: observed, level, and OD Factored trip tables.

Observed seed tables, which were discussed in the preceding section, represent a typical solution. The evaluations will determine how each software utilizes the prior information. Another possible initial trip table is the level trip table, in which each cell contains an identical value. Tables 1.7 and 1.9 show the two level trip tables, for the Gur 730 and Village networks, respectively. An analysis will be performed in later chapters to investigate the effects that various level cell values have on the calculated O-D tables. Lastly, a trip table can be generated with the production and attraction sums factored through a program written by Professor Fricker of Purdue University [Fricker, 1986]. This is simply a balanced trip table with respect to production and attraction values. The idea is that the use of a factored trip table may result in a better O-D table than a level trip table, because the zone-by-zone origin and destination totals are conserved, although network structure and traffic conditions are not incorporated. OD Factored tables can be seen in Tables 1.8 and 1.10. One feature of the trip table that is shared by the three O-D packages to be tested in this study (Chapters 2-4) is the preservation of zero cells. When a zero value is used in an initial trip table, the calculated matrix will retain that characteristic. In other words, zero cells will remain zero.

Table 1.7 Level Trip Table (Gur 730 Network)

FROM/TO	1	2	3	4	5	6	TOTAL
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0
4	0	100	100	0	0	100	300
5	100	100	100	100	0	100	500
6	0	100	100	100	0	0	300
TOTAL	100	300	300	200	0	200	**1100**

Table 1.8 OD Factored Trip Table (Gur 730 Network)

FROM/TO	1	2	3	4	5	6	TOTAL
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0
4	140	1347	281	0	0	612	2380
5	249	2395	499	1387	0	1088	5618
6	110	1059	221	613	0	0	2003
TOTAL	499	4801	1001	2000	0	1700	**10001**

Table 1.9 Level Trip Table for the Village Network

FROM/TO	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	TOTAL
1	0	100	100	100	100	100	100	100	100	100	100	100	100	100	100	1400
2	100	0	100	100	100	100	100	100	100	100	100	100	100	100	100	1400
3	100	100	0	100	100	100	100	100	100	100	100	100	100	100	100	1400
4	100	100	100	0	100	100	100	100	100	100	100	100	100	100	100	1400
5	100	100	100	100	0	100	100	100	100	100	100	100	100	100	100	1400
6	100	100	100	100	100	0	100	100	100	100	100	100	100	100	100	1400
7	100	100	100	100	100	100	0	100	100	100	100	100	100	100	100	1400
8	100	100	100	100	100	100	100	0	100	100	100	100	100	100	100	1400
9	100	100	100	100	100	100	100	100	0	100	100	100	100	100	100	1400
10	100	100	100	100	100	100	100	100	100	0	100	100	100	100	100	1400
11	100	100	100	100	100	100	100	100	100	100	0	100	100	100	100	1400
12	100	100	100	100	100	100	100	100	100	100	100	0	100	100	100	1400
13	100	100	100	100	100	100	100	100	100	100	100	100	0	100	100	1400
14	100	100	100	100	100	100	100	100	100	100	100	100	100	0	100	1400
15	100	100	100	100	100	100	100	100	100	100	100	100	100	100	0	1400
TOTAL	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	1400	21000

Table 1.10 OD Factored Trip Table for the Village Network

FROM/TO	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	TOTAL
1	0	13	170	38	22	16	10	62	148	280	26	22	3	13	41	864
2	32	0	24	5	3	2	1	9	21	40	4	3	0	2	6	152
3	174	10	0	30	17	12	8	48	115	217	21	17	2	10	32	713
4	38	2	29	0	4	3	2	10	25	47	4	4	0	2	7	177
5	60	4	45	10	0	4	3	17	40	75	7	6	1	4	11	287
6	61	4	47	10	6	0	3	17	41	76	7	6	1	4	11	294
7	63	4	48	11	6	4	0	17	42	79	7	6	1	4	12	304
8	62	4	47	11	6	4	3	0	41	78	7	6	1	4	11	285
9	240	14	183	41	24	17	11	67	0	300	28	24	3	14	44	1010
10	422	25	322	72	42	30	20	117	280	0	50	41	5	25	78	1529
11	22	1	17	4	2	2	1	6	14	27	0	2	0	1	4	103
12	53	3	41	9	5	4	2	15	35	67	6	0	1	3	10	254
13	52	3	40	9	5	4	2	14	35	65	6	5	0	3	10	253
14	54	3	41	9	5	4	2	15	36	67	6	5	1	0	10	258
15	36	2	27	6	4	3	2	10	24	45	4	4	0	2	0	169
TOTAL	1369	92	1081	265	151	109	70	424	897	1463	183	151	19	91	287	6652

1.2 Error Analysis

Statistical measures are required to compare the test results. In this study two types of measures are used: one- and two-dimensional tests. A one-dimensional test is used for link-to-link (LTL) comparison and total production and attraction (P/A) correlation analysis. The LTL values are provided by each of the software as part of the output at the end of O-D calculation. The values for P/A comparisons are obtained from the calculated O-D table by summing matrix rows and columns. RMSE and %RMSE are generally used in transportation studies. %RMSE is used instead of RMSE because of its characteristics in normalizing values. A two-dimensional test is used for actual trip table comparisons. Chi-square is generally used for two-dimensional arrays. Some problems exist and will be discussed in Section 1.2.2. For the comparison between two values, mainly the total observed and calculated system trip values, a percentage difference is used.

1.2.1 %RMSE Test

Different software packages have different definitions for %RMSE, or at least they have different applications of the measure. According to THE's user guide, the term refers to a comparison between the assigned link volumes and the observed link counts. For example, if the %RMSE was calculated to be 9%, this would indicate that 68% (one standard deviation) of the assigned volumes are within 9% of the observed volume [Bromage, 1991]. The variables are defined as follows:

$$\%\mathrm{RMSE} = \frac{\sqrt{\left(\frac{\sum(\mathrm{GC}-\mathrm{AV})^2}{\mathrm{N}}\right)}}{\frac{\sum \mathrm{GC}}{\mathrm{N}}} \times 100\%$$

N = Number Of Links With Counts
GC = Ground Count For Each Link
AV = Assigned Volume For Each Link

According to CTPS, the Trip Table Estimation module would produce a trip table with a better %RMSE than when the table is assigned to the network. The manual explains that the trip estimation routine saves the cell values as real numbers, but during the assignment phase they are rounded off to integers. For example, the Gur 730 network calculation produces %RMSE of 0.1495% for the Trip Estimation Module, but 0.23% after the table has been assigned back onto the network. Although these values are different, they are both well below the 40% level generally considered to be acceptable. %RMSE is chosen over the RMSE measure because it gives a more meaningful comparison between the test networks of completely different size, loading volumes, and conditions. In another words, the comparison is not skewed due to the magnitude of the trip volumes. For example, a comparison of two series of values will produce the same %RMSE as the same series that are 10 times the magnitude. The same comparison in terms of RMSE will produce error value that is 1/10th of the second series.

1.2.2 Chi-Square Test

The Chi-square variable is used to test how closely a set of observed frequencies corresponds to a given set of expected frequencies; it is defined as [Harnett and Soni, 1991]:

$$\chi^2 = \sum \frac{(O - C)^2}{O}$$

O = Observed Cell
C = Calculated Cell

With this measure, the similarity between trip tables can be quantitatively determined. However, some problems exist in using this measure in the study. First, there is no way to deal with zero cell values due to the design of the $\chi 2$ formula. In O-D studies, zero cells can exist. Another problem is that the measure puts equal weight on the trip cells. This quality is not desirable, because smaller trip cells will dictate the error measure. For example, an observed cell value of 10 compared with a calculated value of 20 will give much a large $\chi 2$ value than an observed cell of 100 compared with a calculated value of 120. A difference between the observed and calculated cells will show different error measure depending on the magnitude of the observed cell. Due to the lack of a suitable two-dimensional measure, trip tables are rearranged into one-dimensional arrays and %RMSE will be used as a relative measure of goodness of fit.

1.2.3 %Difference Comparison

The comparison between total system trips is represented by %Difference, it is defined as:

$$\%\text{Difference} = \frac{(\text{Observed} - \text{Calculated})}{\text{Observed}} \times 100$$

For example, if a %Difference value is negative, this means the calculated system trips are overestimated.

1.3 Software Evaluation

In the first part of this document (Chapters 2-4), three software packages that are capable of calculating O-D tables given link information will be evaluated. They are The Highway Emulator (THE), PC-LINKOD, and Fast Matrix Calibration (FMC). Each program utilizes a different theory to calculate trip tables. The methods are Maximum Entropy, User Equilibrium, and Information Minimization with Elasticities, respectively. Some of the topics discussed about the software will be a brief history and development, advantages and shortcomings, things to watch out for, how to perform O-D calculations, required input, and sensitivity analysis on various components. The sections on how to perform the O-D calculation serve as a supplemental guide to the user manual supplied by the software developer or distributor. Past experience has shown some procedures are not explained clearly in the user manual or are entirely overlooked.

1.4 Software Selection

In Chapter 5 the three software packages will be compared side by side and one will be recommended for the use on the Indiana network. Some of the issues discussed will be the reliability of the calculated O-D tables, capacity of the software, error checking ability, ease of use, and flexibility. First of all, a reliable and stable package is essential. The research is dealing with a large network, so the chosen software must be able to handle large numbers of node and link data. Error checking capability is not mandatory, but is highly recommended. Lastly, flexibility of the software packages is discussed. This is an important feature, because different scenarios and loading conditions may present problems in modifying the input and control files.

1.5 Building the Indiana Network

In a study of this magnitude, the level of detail of the network needs to be defined at the beginning. The network should have as much detail as needed for planning and programming purposes and to represent network characteristics accurately, but be simple enough to reduce data storage, data manipulation, and computational effort. Zone boundaries should conform to data collected by INDOT and other agencies. In this study, internal zones are defined by counties, which is consistent with the available data. The current level of detail is designed to provide access to all 92 counties and external gateways. The current network will have as its basis the National Highway System (NHS) network, which contains the Interstate and most State highways. Fortunately, a base network has been provided to the Purdue researchers by Professor William Black of Indiana University [Black, 1993]. The network data is stored in TransCAD, which is a GIS software package. A connection will be created between TransCAD and the chosen software so the transformation of data from the GIS to the software can be performed. This will be done through computer programs written specially for the conversion process. Details of the network and related issues will be discussed in Chapter 6.

1.6 Implementation of Chosen Package(s)

Chapter 7 will discuss issues related to the application of FMC. Many unforeseen potential problems exist, but are only discovered when the actual work is underway. Because of the size of the network, some programs are written to lessen the task of repetitious work such as building level trip tables. One example is a program to build an OD Factored trip table from thousands of lines of link data. In addition, a spreadsheet is introduced as a tool to reformat data output. In Chapter 8, an alternative method for generating initial trip tables while be considered.

1.7 Results and Further Research

In this study, the goal is to find a suitable, reliable computer package to generate O-D tables based on vehicle link counts and network characteristics. Chapter 9 will discuss the results and offer recommendations for future O-D estimation research. The final O-D calculations will include a comparison of various software-specific parameter settings, with the goal of achieving an improved match against the traffic counts.

CHAPTER 2 THE HIGHWAY EMULATOR

The Highway Emulator (THE) was developed by Edward J. Bromage at the Central Transportation Planning Staff (CTPS) of the City of Boston. The manual for the release used in this study (version 4.0) was dated April 30, 1991 [Bromage, 1991]. The package is capable of performing the traditional four-step transportation planning process as well as synthesizing O-D tables. The O-D table calculation program is based on ME2 (Maximum Entropy Matrix Estimator) developed by Van Zuylen and Willumsen [Van Zuylen, 1980]. THE's O-D table calculation program has one constraint; the assignment of the estimated trip table must produce the observed counts. The algorithm works by making the smallest possible adjustments to an initial trip table in order to match the observed volumes. These adjustments are made to as many trip table cells as possible, provided the cell to be adjusted has some or all of its volume assigned to a network link for which actual traffic counts are available [Bromage, 1991]. If a network can be constructed and counts are available for as many links as possible, THE is capable of finding an O-D table that satisfies the link constraints.

THE does some calculation internally and requires only a seed trip table and a network file, which is an attractive aspect of the package. THE as a 4-step travel demand package is capable of working with 300 zones, 2000 nodes, and 3000 links. However, the trip table estimation module only allows 300 nodes and 500 links. The trip assignment step can be done using capacity constrained or equilibrium trip assignment.

2.1 Advantages

The only input data required to perform O-D matrix calculations are the network file and a seed trip table, as discussed in Chapter 1. Although THE does not require a complete set of link data, more information will produce better results.

Values of P_{ija}, the link use proportion, traditionally required by the maximum entropy method, are calculated internally [Bromage, 1991]. The link file specifies the probability that trips on links can be used for O-D pairs. For example, using Gur 730, travel from zone 4 to 3 is possible via two paths: 4-9-11-12-3 or 4-9-10-12-3. Suppose 70% of the travel is on the first path. Then the link use proportion of Links 9-11 and 11-12 would be 0.7 while, the link use proportion of Links 9-10 and 10-12 would be 0.3. The link use proportion of Links 4-9 and 12-3 would be 1.0, because the links are used by 100% of the travel between zone 4 and 3. The Trip Table Estimation Module first assigns the seed trip table to the specified network. While the trip assignment is in progress, a link use probability file is created [Bromage, 1991].

2.2 Shortcomings

All input files for THE are best entered from a keyboard. This makes the revision and editing of the network difficult, with no way to check the network by displaying it on screen or printer. THE can accept network files from another model, such as MINUTP, but the conversion is not straightforward and makes editing the network file necessary [CTPS]. Caliper Corporation, the maker of TransCAD, has developed a procedure within TransCAD that is able to convert files directly into THE. The procedure has not been tested by Purdue University researchers for this project.

The capacity of THE may be another disadvantage of the program for a larger network. The ability to handle only 500 nodes limits the detail that may be required by the Indiana network. THE's requirement that trips must be conserved at every node poses a problem that needs attention. Realistically, trips flow in and out of intersections may not conserved due to errors such as counting errors. A node balancing program is possible to balance the trips in and out of the nodes [Beagan, 1986 and Fricker, 1988]. The problem associated with this technique is the possibility of lost network information that a large adjustment could be made to change the characteristic of the traffic flow information.

2.3 Things to Watch Out for

This section will illustrate in detail the specific items that are pertinent in successfully preparing files for THE matrix calculations. Only two files are required in THE: network and seed table files. The seed table is simple and straightforward to construct by following screen commands; therefore emphasis is focused on network coding.

THE requires sequential node numbering; no gaps are allowed in the network coding. The internal zones must be numbered first, then the external zones. There can be no gaps in the zone numbering scheme. For example, the highest node allowed is 2000 -- this is the highest number that can be used, but keep in mind the limitation of 500 allowed by the trip table estimation module. A link is defined by its end nodes. THE allows two-way links but, when dealing with a one-way link, the required format is A-node to B-node. THE does not recognize nodes with more than four incident links; the links beyond the fourth connector are ignored. The solution is to use dummy links. This will be explained in Section 2.4.1.

A network for THE must be constructed so that there can be paths built from and to every zone, or else error messages may appear as calibration process is taking place. However, in practice, this is not necessary to obtain reasonable results. In the Gur 730 network, not every zone has paths to and from other zones, but the network still worked properly. Links cannot connect to zone centroids directly so dummy links and at least one intermediate node must be used to connect the zones. This is done in Gur 730 by the addition of Node 13. The reason is that path building can not utilize zone connectors.

2.4 How to Perform O-D Table Calculations

There are 12 modules within THE. When the MENU command is invoked, the screen looks like Figure 2.1. While in this menu screen, all the operations can be executed simply by entering the first letter key of the module. The following modules are used to perform trip table estimation:

N (etwork editing program
A (ssignment program
L (ink/roadway segment volume output program
C (alibration of a trip table program, and
M (atrix editing menu

The next few sections will explain these modules in depth and offer some helpful hints on how to operate them. They are discussed in their order of operation.

```
(T)he  (H)ighway  (E)mulator : MAIN MENU

              N (etwork editing program
              R (estrict turning movements menu
              S (ocio-econmic data file menu
              T (ravel time matrix program
              G (ravity model program
              A (ssignment program
              V (converter program
              L (ink/roadway segment volumes program

              C (alibration of a trip table program
              M (atrix editing menu

              I (ntersection data file menu
              O (utput intersection volumes program

              F (ratar model for forecasting
              D (iffer model for forecasting

              Q (uit THE
make selection :

Software Developed by: Edward J. Bromage, CTPS, 10/11/89
```

Figure 2.1 THE Menu Screen

2.4.1 Network Editing Program

The network is created and edited within this module. This is by far the most important step of O-D table estimation by THE. An accurate network is essential to a realistic estimated trip table. The following attributes are required for the network links: node numbers at each end, link length (.01-10.00 miles), free flow speed, one- or two-way direction, additional fixed delay (i.e., the time it takes to enter the network from a zone centroid), hourly capacity for each direction, and traffic count for each direction. A blank worksheet is available by selecting the "I" command from the menu while in this module.

The restriction of a node to no more than four incident links is resolved by using dummy links. An example is illustrated in Figure 2.2. Node 6 has five connecting links, which is not allowed by THE. An additional node (Node 7) is added next to the node at a distance of 0.01 mile, the minimum link length allowed in THE. The added distance has a minimal effect in the network because the additional distance is so small [Bromage, 1991]. Two or more links now can be connected to the new node. This will satisfy THE requirement that no more than four links be incident to any node.

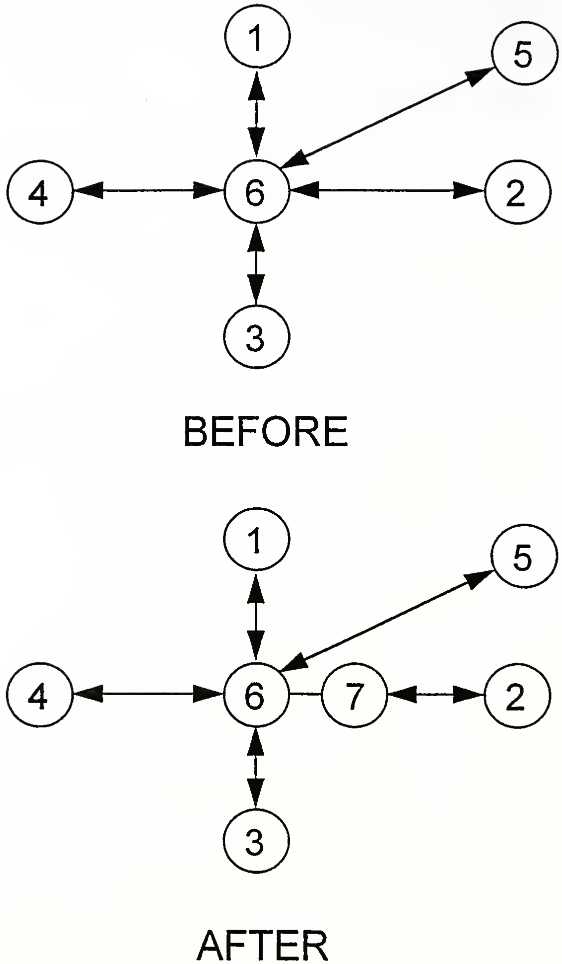

Figure 2.2 Five-Link Scenario and Solution

2.4.2 Matrix Editing Menu

The seed table is created and edited here. Since THE saves the trip table in its original file, if the same trip table is needed for another calculation, use the "COPY" command in DOS to create extra sets of the trip table. The calculated O-D table is viewed and printed within this module. To obtain a hard copy of a trip table without unnecessary information output, the "PRINT SCREEN" key will accomplish the task.

2.4.3 Calibration of a Trip Table Program

This is where the actual O-D calculation occurs. Before running this module, make sure there is a network file and a seed table. The link use probabilities, P_{ija}, are calculated automatically within this module. The user manual suggests using equilibrium assignment with five iterations due to its theoretical superiority and good convergence behavior [Turnquist and Gur, 1979]. A sensitivity analysis on the number of iterations used will be performed in Section 2.6.1.

2.4.4 Assignment Program

This module loads the network according to a specified trip table, in this case, the calculated O-D table. No output is produced in this module; the following module will produce the output.

2.4.5 Link/Roadway Segment Volume Output Program

Three separate outputs are produced, along with a few options. First output is the link-to-link comparison of the assigned volume and the actual volume. The next output is Percent Root Mean Square Error (%RMSE) stratified by the volume ranges, along with the names of the files used for computation. The last output is the detailed breakdown of trips through each zone; this is also known as select link analysis. This file can be viewed only after printing a hard copy.

2.5 Running THE

Three initial tables are used for the two test networks discussed in Chapter 1: observed, level, and OD Factored trip tables. In Gur 730 network, the observed seed table is the O-D table resulted according to Beagan's assumptions. For the Village network the observed trip table is the O-D table resulted from license plate survey.

2.5.1 Test Networks

Mark Turnquist and Yehuda Gur [Turnquist and Gur, 1979] created the network, which has since been adopted as a test network by CTPS [Beagan, 1991a,b]. A slightly modified network is created to be certain the equilibrium assignment works properly [Beagan, 1991a]. The only difference between the two networks is the link distance on link 9-10, where modified network has a distance of 7.01 miles, while original network has a distance of 7 miles. Five iterations and equilibrium assignment options are chosen for the calibration process [Bromage, 1991]. Six O-D tables are resulted from 2 networks and 3 initial that are shown in Tables 2.1-2.6. For the Village network, the calculated trip tables are shown in Tables 2.7-2.9.

Table 2.1 O-D Table for Original Gur 730 with Beagan Initial Matrix (THE)

FROM/TO	1	2	3	4	5	6	TOTAL
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0
4	0	610	377	0	0	1413	2400
5	500	3902	338	575	0	285	5600
6	0	288	285	1424	0	0	1997
TOTAL	500	4800	1000	1999	0	1698	9997

Table 2.2 O-D Table for Modified Gur 730 with Beagan Initial Matrix (THE)

FROM/TO	1	2	3	4	5	6	TOTAL
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0
4	0	508	300	0	0	1593	2401
5	500	4092	475	425	0	107	5599
6	0	200	224	1559	0	0	1983
TOTAL	500	4800	999	1984	0	1700	**9983**

Table 2.3 O-D Table for Original Gur 730 with Level Initial Matrix (THE)

FROM/TO	1	2	3	4	5	6	TOTAL
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0
4	0	630	530	0	0	1238	2398
5	500	2781	164	1692	0	463	5600
6	0	1388	307	308	0	0	2003
TOTAL	500	4799	1001	2000	0	1701	**10001**

Table 2.4 O-D Table for Modified Gur 730 with Level Initial Matrix (THE)

FROM/TO	1	2	3	4	5	6	TOTAL
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0
4	0	520	300	0	0	1591	2411
5	500	4080	474	434	0	109	5597
6	0	200	225	1559	0	0	1984
TOTAL	500	4800	999	1993	0	1700	**9992**

Table 2.5 O-D Table for Original Gur 730 with OD Factored Initial Matrix (THE)

FROM/TO	1	2	3	4	5	6	TOTAL
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0
4	2	627	522	0	0	1250	2401
5	500	2765	177	1707	0	450	5599
6	2	1408	301	293	0	0	2004
TOTAL	504	4800	1000	2000	0	1700	**10004**

Table 2.6 O-D Table for Modified Gur 730 with OD Factored Initial Table (THE)

FROM/TO	1	2	3	4	5	6	TOTAL
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0
4	2	509	300	0	0	1594	2405
5	500	4091	476	424	0	106	5597
6	2	200	224	1560	0	0	1986
TOTAL	504	4800	1000	1984	0	1700	9988

Table 2.7 O-D Table for the Village Network with Observed Initial Matrix (THE)

FROM/TO	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	TOTAL
1	0	41	22	48	31	7	4	371	11	308	2	8	1	7	14	875
2	24	0	0	0	0	0	0	0	78	27	4	0	0	0	0	133
3	122	0	0	51	30	3	1	13	315	115	45	0	8	1	15	719
4	47	0	6	0	1	0	0	1	69	61	12	0	0	0	7	204
5	75	0	9	3	0	0	0	3	111	98	18	0	0	0	12	329
6	31	23	6	1	1	0	0	1	12	111	2	93	0	4	7	292
7	18	0	37	8	5	0	0	1	85	64	13	0	0	23	42	296
8	0	7	31	28	19	4	2	0	12	162	2	5	0	5	8	285
9	16	0	759	21	12	9	1	1	0	48	33	0	0	0	54	954
10	920	2	92	50	30	69	49	24	93	0	34	80	10	73	23	1549
11	2	0	62	2	1	1	0	0	13	10	0	0	0	0	5	96
12	11	1	30	14	6	0	0	1	0	326	0	0	0	0	7	396
13	16	0	15	3	1	0	0	1	129	76	25	0	0	4	13	283
14	24	40	13	1	1	14	2	1	3	76	0	39	0	0	45	259
15	69	0	9	39	14	2	0	3	10	9	1	0	0	1	0	157
TOTAL	1375	114	1091	269	152	109	59	421	941	1491	191	225	19	118	252	6827

Table 2.8 O-D Table for the Village Network with Level Initial Matrix (THE)

FROM/TO	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	TOTAL
1	0	31	22	58	33	8	4	369	15	294	3	9	1	8	16	871
2	22	0	0	0	0	0	15	0	56	28	10	0	2	0	0	133
3	129	0	0	54	31	2	1	5	296	118	53	0	11	2	14	716
4	49	0	6	0	1	0	0	2	57	61	11	0	11	0	8	206
5	79	0	9	2	0	0	0	3	92	98	17	0	17	0	13	330
6	32	36	6	1	1	0	0	1	10	112	1	79	2	3	8	292
7	14	0	34	8	4	1	0	0	99	49	18	0	19	19	48	313
8	0	18	13	33	19	4	2	0	9	168	1	5	1	4	9	286
9	20	0	732	21	12	9	1	1	0	69	25	0	1	0	75	966
10	916	3	113	44	25	68	33	34	125	0	23	78	5	71	12	1550
11	2	0	66	2	1	1	0	0	13	6	0	0	0	0	7	98
12	10	1	33	13	7	0	0	1	0	326	0	0	0	0	3	394
13	21	0	11	3	1	0	0	1	147	71	27	0	0	6	16	304
14	22	26	19	4	3	15	7	1	3	78	0	55	1	0	27	261
15	61	0	8	37	21	1	1	2	16	6	2	0	1	1	0	157
TOTAL	1377	115	1072	280	159	109	64	420	938	1484	191	226	72	114	256	6877

Table 2.9 O-D Table for the Village Network with OD Factored Initial Matrix (THE)

FROM/TO	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	TOTAL
1	0	30	35	52	29	7	4	369	13	303	2	8	1	8	13	874
2	23	0	0	0	0	0	12	1	58	27	12	0	0	0	0	133
3	130	0	0	57	32	2	1	5	293	118	56	0	12	1	15	722
4	49	0	6	0	1	0	0	1	67	62	12	0	0	0	7	205
5	78	0	8	2	0	0	0	3	107	98	20	0	2	0	11	329
6	31	38	6	1	1	0	0	1	12	109	2	80	1	3	7	292
7	15	0	35	8	4	0	0	0	97	54	17	0	2	20	48	300
8	0	20	19	30	16	4	2	0	8	170	2	4	1	4	7	287
9	19	0	727	21	12	8	2	0	0	65	22	0	0	0	79	955
10	913	2	109	47	27	68	38	34	123	0	24	79	6	72	12	1554
11	2	0	67	2	1	1	0	0	11	5	0	0	0	0	8	97
12	11	0	34	13	7	0	0	0	0	326	0	0	0	0	4	395
13	20	0	12	2	1	0	0	1	132	72	24	0	0	6	16	286
14	22	24	21	4	2	16	4	1	3	79	1	54	1	0	28	260
15	63	0	6	36	22	2	1	2	15	6	3	0	0	1	0	157
TOTAL	1376	114	1085	275	155	108	64	418	939	1494	197	225	26	115	255	6846

2.5.2 Findings

THE is very sensitive to the Gur 730 network. The assignment of trips to paths can be very sensitive to the impedance given to the links. In this case, an increase of 0.01 mile on a 7-mile link changed the outcome tremendously.

The first analysis is to determine the validity of calculated trip tables. Table 2.10 displays the fit against production and attraction (P/A) values and Table 2.11 shows link-to-link (LTL) comparisons. In both versions of Gur 730, P/A and LTL measures indicate that the estimated final trip tables are reasonable. The close degree of fit for the Gur 730 network is attributed to the small network size, because little loading variation is allowed. All except three O-D pairs have one travel path. Error measures with the Village network are larger, but still well within the 40% error limit. In a larger network this is to be expected, because of the possibility of multiple paths used in link loading. No major error difference exists for the three initial trip tables in the test networks.

Table 2.10 Production and Attraction Comparisons (THE)

	Production and Attraction (%RMSE)		
Network	Beagan/Observed*	Level	OD Factored
Original Gur 730 Network	0.106%	0.113%	0.165%
Modified Gur 730 Network	0.662%	0.591%	0.634%
Village Network	4.353%	4.766%	4.312%

* Beagan seed table is for Gur 730 and observed seed table is for the Village network.

Table 2.11 Link-To-Link Comparisons (THE)

	Link-To-Link Comparisons (%RMSE)		
Network	Beagan/Observed	Level	OD Factored
Original Gur 730 Network	0.3626%	0.1495%	0.1420%
Modified Gur 730 Network	1.4905%	1.4423%	1.4945%
Village Network	18.98%	18.80%	19.00%

The next comparison determines the ability of THE to produce results to a known solution, in this case, Beagan and observed trip tables for the Gur 730 and the Village networks, respectively. Tabulation of the comparison of known matrices can be seen in Table 2.12. In the modified Gur 730, the three initial trip tables produced similar results when compared with the Beagan trip table. In the Village network, non of the three initial tables seemed to provide good information. Chapter 5 will have a comparison of this measure against other packages. Next two tables (2.13 and 2.14) show the comparison between the final calculated trip tables of both networks; these values demonstrated the variation between these trip tables. All the final trip tables are considered satisfactory in terms of various error measures discussed above. In the Gur 730 Network and Village networks, OD Factored and level trip tables produced similar results. With the modified Gur 730 network, the difference is less. When an old trip table is not available, OD Factored and level trip tables can be used with THE with satisfactory results.

Table 2.12 Initial Trip Table Comparison (THE)

	Trip Table Comparison (%RMSE)		
Network	Beagan/Observed	Level	OD Factored
Original Gur 730 Network	7.68%	81.15%	82.07%
Modified Gur 730 Network	7.76%	7.29%	7.79%
Village Network	179.10%	174.32%	173.12%

Table 2.13 Gur 730 Network Final Trip Table Analysis (THE)

Original	%RMSE
Beagan O-D vs. Level	74.74%
Level vs. OD Factored	1.369%
OD Factored vs. Observed	74.70%
Modified	
Beagan O-D vs. Level	13.93%
Level vs. OD Factored	0.641%
OD Factored vs. Observed	0.128%

Table 2.14 Village Network Final Trip Table Analysis (THE)

Village Network	(%RMSE)
Observed O-D vs. Level	22.37%
Level vs. OD Factored	9.85%
OD Factored vs. Observed	20.05%

2.6 Sensitivity Analysis

Many aspects of THE are tested to determine the efficiency of the program. These tests include sensitivity analysis on various parts of the program. For THE, the tests involve the values in level target trip tables, the number of iterations needed for a reasonable output without additional time, the creation or destruction of trips, and the use of initial tables other than an old matrix or level trip table.

2.6.1 Number of Iterations

Generally, more iterations is better, but at the expense of computer time. Computer time is relatively cheap these days, except in the case when the user desires a real time matrix calculation. Two sets of calculations are performed for up to 20 iterations. Error plots (RMSE) of the original Gur 730 network and the Village network with a level seed table are shown in Figure 2.3. In both groups, the magnitude of %RMSE decreased as the number of iterations increased, which is expected. The smooth curves in the figure illustrate the stable convergence behavior. The user manual suggested 5 iterations, which correspond to the findings.

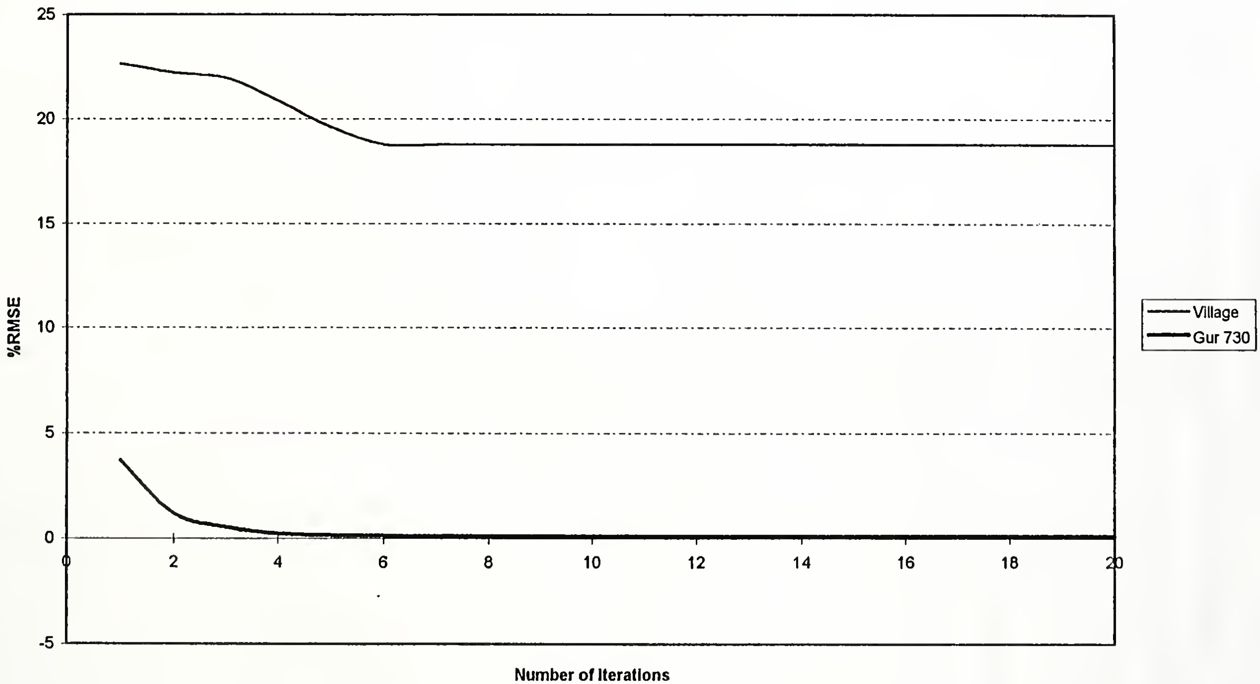

Figure 2.3 Number of Iteration Test (THE)

2.6.2 Level Trip Table Sensitivity Analysis

When no a priori table is available, the alternative so far in this study is to use a level or an OD Factored trip table. If a level trip table is to be used, what magnitude should the cell value be? Does one table differ from another? A sensitivity analysis was carried out to determine the results from various level trip tables, using initial cell values ranging from 1 to 9000. THE's Matrix Program has a utility with which one can assign the same value to all the cells within the table. The trip tables resulting after five iterations are identical, no matter what the initial trip table cell values were. A value of 910 was used for the Gur 730 network, because this was the total number of trips in the network: 10,000 divided by the number of non-zero zones, 11. Similar calculations are performed with the Village network, and a value of 30 is obtained. In addition to the above trip tables, other tables were used that have more and less than the total system trips in the two networks. The test is carried out to identify if an underestimated or an overestimated initial trip table would affect the outcome, because the initial trip table is used by the program as a target trip table that the calculated trip table would most resemble while other conditions are met. The values used for Gur 730 were 1, 10, 100, 500, 910, and 9000. In the Village network, values of 10, 30, and 100 were used in level trip tables. No variance was observed, and calculated trip tables are independent of magnitudes used in the level trip table, because the ratios between the cells are constant.

2.6.3 Does THE Create or Destroy Trips?

The user needs to know if the program destroys or creates trip in the process of calculating the new trip table. This is very important, because the creation or destruction of trips is not desirable. The discrepancy of total system trips of calculated trip tables in terms of percentage difference from both networks are shown in Table 2.15. Total system trips are 10,000 and 6651 for the Gur 730 and Village networks, respectively. The trip tables with origin and destination sums can be seen in Chapter 1.

Table 2.15 Total System Trips Comparison

	% Difference Between System and Calculated Trips*		
Network	Beagan/Observed	Level	OD Factored
Original Gur 730 Network	-0.03%	0.01%	-0.04%
Modified Gur 730 Network	0.17%	0.08%	0.12%
Village Network	-2.646%	-3.398%	-2.932%

*Negative = Overestimate

2.7 Conclusion

THE worked well for small- and medium-sized networks. It is a very efficient program, but very network sensitive. O-D calculations are simple to perform, once the procedures become familiar to the user. The best part of the package is the input requirements: only two files are required. A level trip table works as well as OD Factored trip table when no known information is available; as more information is known, THE can utilize the additional data through the seed trip table. OD Factored and level trip tables produced similar results. The magnitude of level matrix cell entries has no effect on the outcome. THE is not sensitive to level seed tables, except to conserve network characteristics, in the case of zero cell values. Network coding is very important in small networks, as shown with the two slightly different Gur 730 Network networks.

Lack of ways to enter data, except from the keyboard, is the biggest disadvantage of THE. Editing and revising the network would be extremely time consuming and accuracy not guaranteed, because everything is entered from the keyboard. In addition, editing of the network is done by calling one link at a time. This is unacceptable when dealing with a large network, because immense patience is required. Although TransCAD has a procedure to convert files into THE format, some tests should be performed to verify its validity before it can be used.

CHAPTER 3 PC-LINKOD

PC-LINKOD is a PC version of the mainframe LINKOD developed for FHWA [Gur et al., 1980b]. LINKOD was specifically designed for small, congested urban areas. The PC-LINKOD program was provided to us by Professor Wende O'Neill when she was at Utah State University. According to Professor O'Neill, a version coded in C with expanded capacity should be available in the near future. Currently, the program (a test version) is coded in FORTRAN and can handle 27 zones, 155 nodes, and 100 links. Initial trip tables in PC-LINKOD represent target trip tables that the solution should approach. The discrepancy between the final trip table and the initial trip table reflects adjustments made to insure that the final trip table is capable of reproducing observed link volumes [O'Neill and Sivanandan, 1989]. Two program termination criteria are used: maximum number of iterations and a convergence parameter for estimated values (Mean Absolute Error, MAE). The program uses heuristic method in modified Frank-Wolfe algorithm and Moore's tree-tracing algorithm in building skim trees [O'Neill and Sivanandan, 1989]. Dial's assignment algorithm is used in determining link volumes and the golden section search algorithm is used to achieve model convergence [O'Neill and Sivanandan, 1989].

3.1 Advantages

All the files necessary to perform O-D calculations are in ASCII format, which eliminates the need to learn a software-specific editor. This means that the network file can be obtained from another source, from GIS, or from other transportation modeling software, with minimal revision required. For example, with the statewide network database in stored in TransCAD, the network connectivity and node positions can be verified on-screen before the data are transformed into PC-LINKOD format. This reduces the time needed to examine and debug the data manually. When no suitable editor is available, the user may look into spreadsheet or database packages to assist the construction and modification of the network files. Because of PC-LINKOD's free format (space- or comma-delimited), the data can be directly used without further editing. A spreadsheet is a better tool in this case, because necessary calculations can be performed in the spreadsheet and the results exported in a space-delimited format. Like THE, the calculated trip table retains characteristics of the seed table, i.e., zero cell values. PC-LINKOD is easy to learn, because a set of sample input files is included with the package. The actual executable program contains only one file, so the need for large computer storage is eliminated. The size of storage depends solely on the size of the network. No other special requirement is needed to run PC-LINKOD.

Three files are required for PC-LINKOD: network, initial trip table, and volume/capacity files. The network file contains node connectivity, distance, and observed traffic counts. The initial trip table file contains the information discussed in Chapter 1. This file serves as a starting point for the software. The last file contains the piecewise linear link performance function [Gur, et al., 1980a]. This function calculates the impedance of links based on the amount of trips. Individual parameters are assigned to each of the links.

3.2 Shortcomings

Due to the nature of the program (equilibrium methods), complete link counts are required in order to perform the O-D table calculation with satisfactory results [Han and Sullivan, 1982]. This is probably the most critical restriction of the software, because getting a complete set of consistent link counts for a large network is time consuming and very costly, if not impossible. For the Indiana network, the problem of link count information is resolved because TransCAD's database has a complete set of link information. Due the piecewise version of the Bureau of Public Roads (BPR) curve, which serves as an approximation to the original equation, some discrepancy may occur in the computed impedances. Section 3.4.3 will discuss this equation in detail.

Designed for testing purposes, the size network that PC-LINKOD can currently handle is only 27 zones, 155 nodes, and 100 links. Due to this capacity restriction, PC-LINKOD cannot be tested on the Village network. There will be two sets of evaluations of PC-LINKOD in Chapter 5, so the lack of test data on the Village network will be compensated for. The source code for LINKOD has been loaned to us by Professor O'Neill, which would enable us to solve the problem of limited capacity. This particular enlarged computer program is designated LINKOD, to distinguish it from PC-LINKOD. A parallel study of LINKOD was undertaken by another researcher at Purdue University.

3.3 Things to Watch Out for

The PC-LINKOD input files are easy to construct. Because they are in ASCII format, files must be comma- or space-delimited. All the fields are required to have information provided, even if the field has a zero value, or the program will read the fields incorrectly [O'Neill, 1992]. Stopping criteria for PC-LINKOD are based on one of two user-specified parameters: acceptable error (MAE) between observed and assigned link volumes, and maximum number of iterations [O'Neill, 1992].

3.4 How to Perform the O-D Table Calculation

The three files essential to perform the O-D matrix calculation are: the network data, seed trip table, and volume/capacity function parameter files. The following sections will discuss each file in detail.

3.4.1 Network Data File

Network data are created, edited, and stored in this file. The first line of the file contains information regarding the network. Eight fields are included in the first row: number of links, number of nodes, number of zones, maximum number of iterations, Golden Section Search (GSS) convergence parameter, convergence parameter for the estimated volumes, print parameter 1, and print parameter 2. If print parameter 1 equals "1", then link volumes are printed after each iteration. If print parameter 2 equals "1", then the trip table is printed after each iteration [O'Neill, 1992]. Care should be taken in using either of these two parameters, because enough information could be generated to fill the computer's hard drive. An example using the Gur 730 Network is shown in Table 3.1.

Beginning with the second row, each line contains information about a link. Four fields are used to convey one-way link information: A-node, B-node, free-flow time, and observed volume. No units are given for free-flow time and observed volume, so units should be devised in advance and applied consistently while preparing this file. For the tests done in this chapter, units of "minutes" and "whole numbers" are used for free-flow time and observed traffic counts. In coding of the network, centroid connectors and links can be listed in any order. In a large network, a recommended coding technique is to put the centroid connectors before the links, so that the data are laid out in a consistent and easy to understand fashion and the centroid connectors can be easily identified.
Zone connectors need not be listed before the links, but this can be a risky practice, because a trip may go through a centroid if the path impedance is less than using only network links.

Table 3.1 PC-LINKOD Network File Format (Gur 730 Network)

```
 19 12 6 50 .01 10 0 0
 4   9   7 2400
 5   7   7 5000
 5   8   7  500
 5 13 15   100
 6 10   7 2000
 7   1   7  500
 7   9 15 4500
 8 10 15  500
 9   4   7 2000
 9 10   7 1500
 9 11 15 4900
10   9   7 1500
10   6   7 1600
10 12 15   900
11   2 15 4800
11 12   7   300
12   3 15 1000
12 11   7   200
13   6 15   100
```

3.4.2 Initial Trip Table File

A square matrix is used for the trip table file; the number of rows must equal the number of columns, which corresponds to the number of zones. Any cell value where travel is possible must have a value greater than zero [O'Neill, 1992]. In cases where travel between zones is possible but a reasonable estimate is not known, a value of .01 will satisfy the condition that the cell value needs to be larger than zero. Consider using an automated method such as a simple program or spreadsheet when constructing a large matrix with level entries to decrease the data entry workload.

3.4.3 Volume/Capacity Function Parameter File

As illustrated in Figure 3.1 [O'Neill, 1992], four parameters are required for each network link. The four corresponding fields are VCRIT, FCRIT, SLOPE1, and SLOPE2. Generally, VCRIT is the link capacity at Level of Service C and FCRIT is the corresponding travel time. The following equation is found in Gur's paper [Gur, 1981]:

$$\mathrm{Ca}(\mathrm{Va}) = \overline{\mathrm{C}}\mathrm{a} + \mathrm{ba} \times \left(\overline{\mathrm{V}}\mathrm{a} - \mathrm{Va}\right)$$

where, Ca(Va) = impedance of link at volume Va,
$\overline{\mathrm{V}}\mathrm{a}$ = observed volume,
$\overline{\mathrm{C}}\mathrm{a}$ = impedance at the observed volume, and
ba = a parameter
Va = volume Va

To apply the above equation with Gur 730 and to comply with the volume/capacity diagram, two assumptions are made in the volume/capacity file to obtain the two slope values. Critical volume (VCRIT) is assumed to be 90% of the observed volume, and the corresponding impedance (FCRIT) is derived by taking the average of free flow and observed impedances. For SLOPE1, the equation is as follows:

FCRIT = Freeflow_Time + SLOPE1 * (VCRIT)

For "SLOPE2", Gur's equation transforms to:

Observed_Time = FCRIT + SLOPE2 * (Observed_Volume - VCRIT)

For example, using the sample data files that came with the PC-LINKOD instructions, a link on the network data file has a Freeflow_Time of 7 and an Observed_Volume of 1500. By assuming VCRIT of 1350 and FCRIT of 8.5, SLOPE1 can be calculated, which is 1.111115e-03. SLOPE2 can be derived in the same fashion, which equated to 1.000003e-02. These results are consistent with the example that came with the user manual [O'Neill, 1992]. Using the above equations, the Gur 730 network volume/capacity file is generated and shown in Table 3.2.

Table 3.2 Gur 730 Volume/Capacity File

2160	8.5	0.0014	0.0125
4500	8.5	0.0007	0.0060
450	8.5	0.0067	0.0600
90	17.5	0.1111	1.0000
1800	8.5	0.0017	0.0150
450	8.5	0.0067	0.0600
4050	17.5	0.0012	0.0111
450	17.5	0.0111	0.1000
1800	8.5	0.0017	0.0150
1350	8.5	0.0022	0.0200
4410	17.5	0.0011	0.0102
1350	8.5	0.0022	0.0200
1440	8.5	0.0021	0.0188
810	17.5	0.0062	0.0556
4320	17.5	0.0012	0.0104
270	8.5	0.0111	0.1000
900	17.5	0.0056	0.0500
180	8.5	0.0167	0.1500
90	17.5	0.1111	1.0000

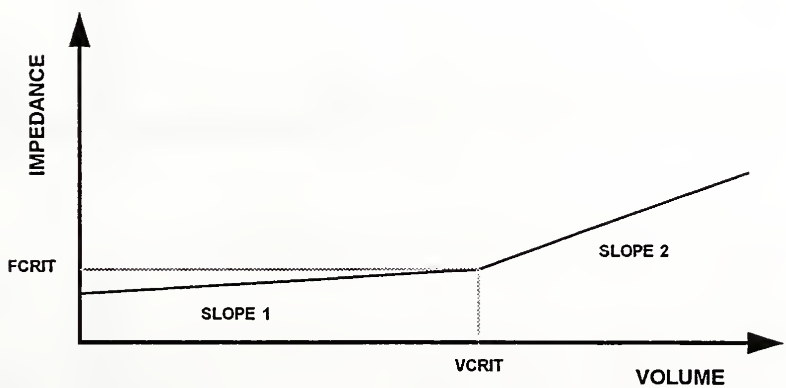

Figure 3.1 Volume/Capacity Diagram

3.5 Running PC-LINKOD

Only the Gur 730 network is used to test the program; PC-LINKOD is too small to handle the Village network. Attempts were made to simplify the Village network but it could not be represented accurately with only 100 links. Three initial tables (discussed in Chapter 1) are used. The results are shown in Tables 3.3-3.5.

Table 3.3 O-D Table with Level Initial Matrix (PC-LINKOD)

FROM/TO	1	2	3	4	5	6	TOTAL
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0
4	0	605.83	522.69	0	0	1278.41	2406.93
5	499.6	2787.43	188.53	1706.19	0	408.12	5589.87
6	0	1399.81	287.09	301.91	0	0	1988.81
TOTAL	499.6	4793.07	998.31	2008.1	0	1686.53	**9985.61**

Table 3.4 O-D Table with Beagan Initial Matrix (PC-LINKOD)

FROM/TO	1	2	3	4	5	6	TOTAL
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0
4	0	570.19	400.38	0	0	1415.21	2385.78
5	497.51	3949.24	322.68	551.69	0	273.37	5594.49
6	0	273.83	275.32	1439.04	0	0	1988.19
TOTAL	497.51	4793.26	998.38	1990.73	0	1688.58	**9968.46**

Table 3.5 O-D Table with OD Factored Initial Matrix (PC-LINKOD)

FROM/TO	1	2	3	4	5	6	TOTAL
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0
4	71.89	946.29	430.59	0	0	1011.53	2460.3
5	508.36	2763.67	278.93	1582.56	0	710.32	5843.84
6	56.48	1128.09	228.54	541.39	0	0	1954.5
TOTAL	636.73	4838.05	938.06	2123.95	0	1721.85	**10258.64**

3.5.1 Findings

The production and attraction (P/A) test shown in Table 3.6 is the first step in validating the results found by PC-LINKOD. Beagan and level trip tables show similar results, while the OD Factored table produced a mediocre result. The next comparison, seen in Table 3.7, is the link-to-link comparison. It also reveals that an OD Factored table produced inferior results when used as an initial trip table. A level trip table (910 in each cell value) worked the best in matching link counts. However, all three trip tables produced results that could be accepted because they are well within the 40% threshold limit. Again, the nearly perfect match of Beagan and level trip tables are because of the simplicity of the test network. The Gur 730 network is designed for testing purposes only. There are only three O-D pairs that have 2 paths, while the rest have only a single path between zones.

Table 3.6 Production and Attraction Comparison (PC-LINKOD)

Production and Attraction (%RMSE)		
Beagan	Level	OD Factored
0.717%	0.678%	9.164%

Table 3. 7 Link-To-Link Comparisons (PC-LINKOD)

Link-To-Link Comparisons (%RMSE)		
Beagan	Level	OD Factored
0.4117%	0.3259%	7.2946 %

Table 3.8 displays how close the calculated trip tables matched the Beagan trip table. The error measure is obtained by a direct cell-by-cell comparison between initial and final trip tables; a smaller value denotes a smaller variance from the solution. The comparison demonstrated that Beagan's solution is not unique. Other solutions are possible, depending on the initial trip tables used.

Table 3. 8 Initial Trip Table Comparison (PC-LINKOD)

Trip Table Comparison (%RMSE)		
Beagan	Level	OD Factored
7.00%	61.46%	75.23%

The next table demonstrates the uniqueness of each calculated table, using pairwise comparisons. Table 3.9 shows the large %RMSE values that indicate that the three final trip tables are quite different. Level and OD Factored initial trip tables produced closer results than the Beagan trip table, with a %RMSE value of 22.35%.

Table 3.9 Gur 730 Network Final Trip Table Analysis (PC-LINKOD)

	%RMSE
Beagan O-D vs. Level	76.76%
Level vs. OD Factored	22.35%
OD Factored vs. Observed	70.45%

3.6 Sensitivity Analysis

As with THE, the efficiency of the method must be determined before PC-LINKOD can be considered in the final selection for Indiana. With PC-LINKOD, the areas tested are number of iterations, level trip tables, and conservation of trips.

3.6.1 Number of Iterations

This test determines the minimum number of iterations needed for the procedure to converge. The test also can indicate the degree of stability in the error measures, which reflects the solution's stability. The results are seen in Figures 3.2 and 3.3. With a level trip table, the number of iterations reaches 30 before the error measures stabilize. The plot with the Beagan initial table is jagged, with an undesirable tendency to fluctuate, but the degree of fluctuation is not large enough to cause concern. This test should be performed on every network to find the minimum number of iterations for a satisfactory result, because with each network, the complexity of the network is unique. This test would indicate the time needed to calculate trip tables on a real time basis, where actual computer time would be critical.

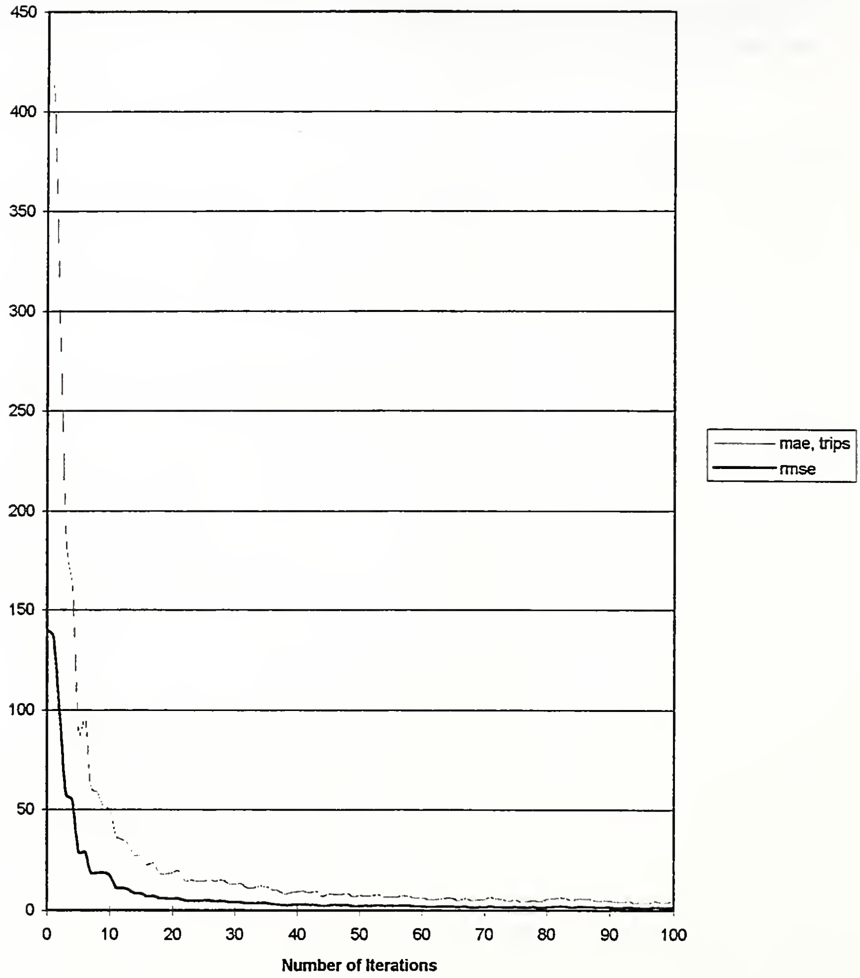

Figure 3.2 Error Plot with Level Initial Trip Tables

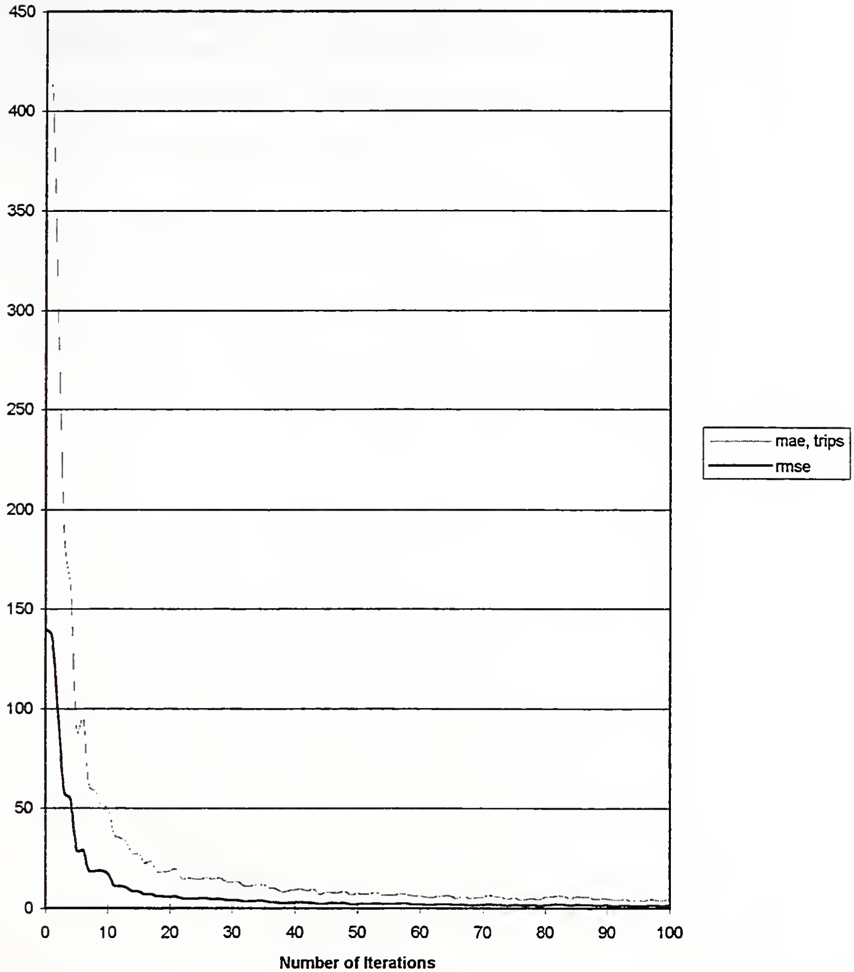

Figure 3.3 Error Plot with Beagan's Initial Trip Table

3.6.2 Level Trip Table Sensitivity Analysis

The range of trip cell values used are from 1 to 9000, while other input variables are kept constant. The results plotted with respect to RMSE are shown in Figure 3.4. The magnitude of the trip tables does not matter as long as enough iterations are permitted. The error measure (RMSE) converged to approximately the same magnitude after 15 iterations. As seen from the trend shown on the graph, they will converge to a very small error as more iterations are allowed.

The next graph, Figure 3.5, shows the comparisons of RMSE and the number of iterations between various levels of trip tables. This is essentially the cross section of Figure 3.4. As the number of iterations increases, the lines are more horizontal, meaning that the magnitudes of level trip tables make little difference. Although the curves for iterations 5 and 10 are erratic, they do stabilize as the iterations continue.

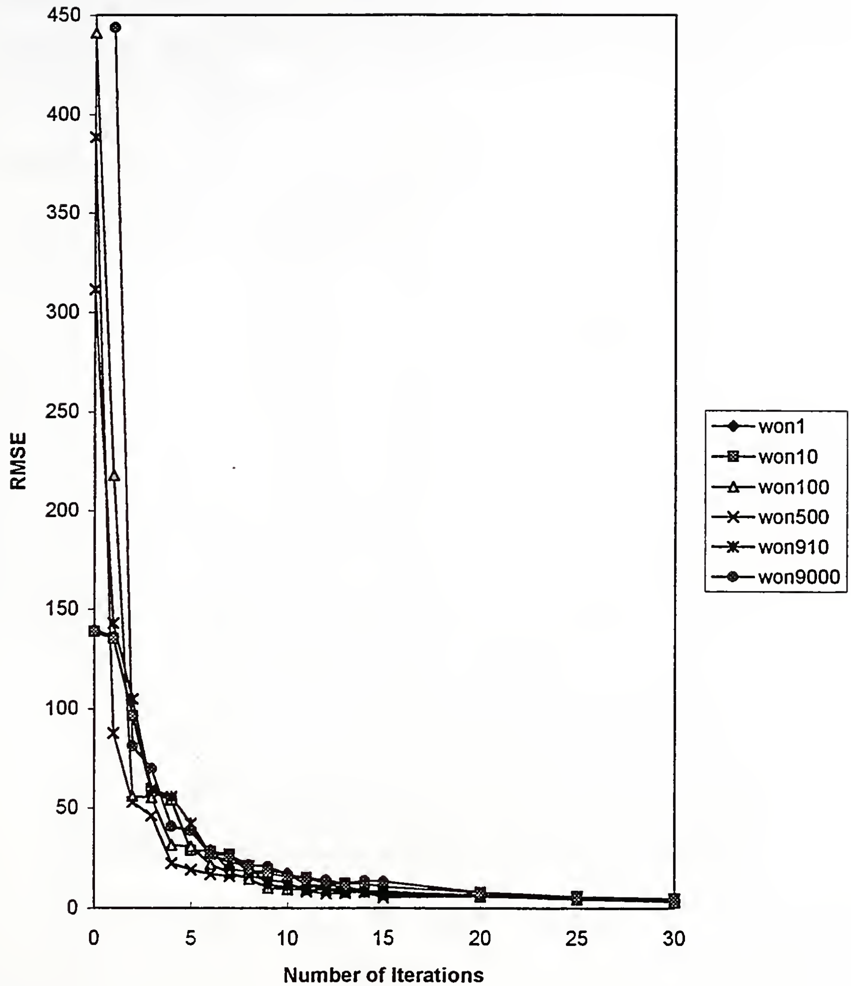

Figure 3.4 Error Plot with Various Level Trip Tables

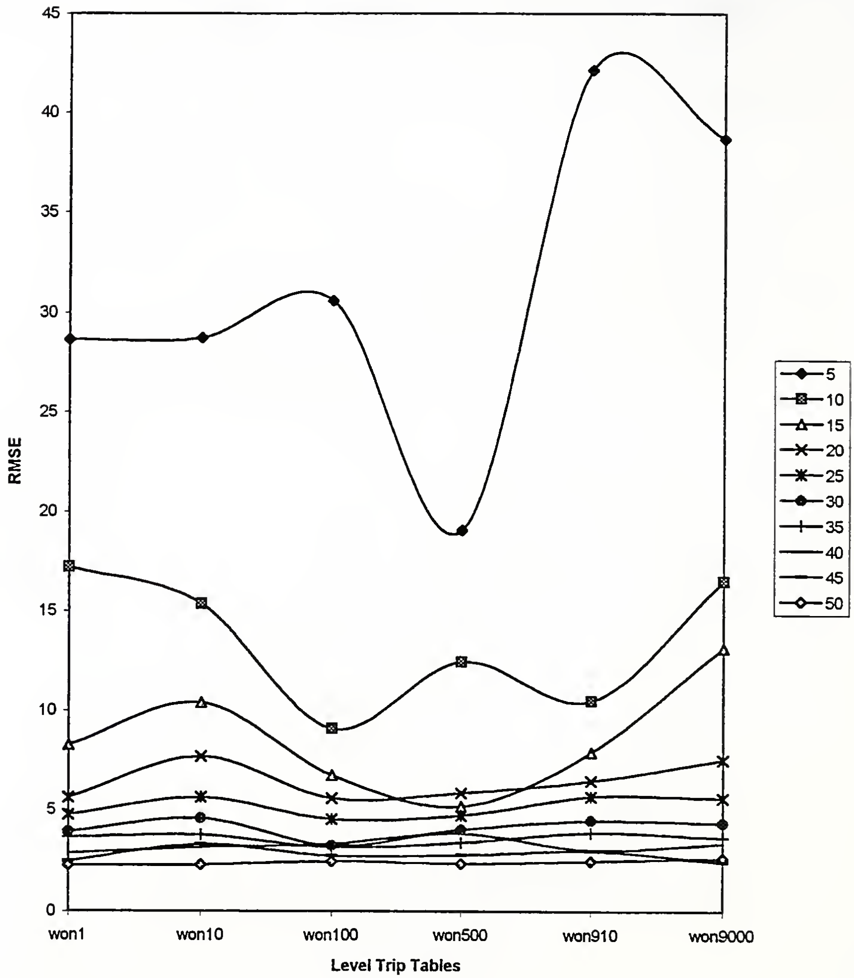

Figure 3.5 Error Plot with Various Level Trip Tables (Cross Section)

3.6.3 Does PC-LINKOD Create or Destroy Trips?

PC-LINKOD preserved total system trips in the Gur 730 network, as shown in Table 3.10. All the calculated trip table came within 1% of total system trips, except for OD Factored. Level initial trip tables conserved the system trips the best; there is no trend as to the best initial cell value to use.

Table 3.10 Gur 730 Network Total System Trips Comparison

Initial Trip Table	% Difference*
Beagan	0.31%
Level 1	0.26%
Level 10	0.14%
Level 100	0.26%
Level 500	0.25%
Level 910	0.18%
Level 9000	0.23%
OD Factored	-2.59%

*Negative = Overestimate

3.7 Conclusion

The test version of PC-LINKOD is promising, simple to operate and produces encouraging results. The free format of PC-LINKOD makes a spreadsheet the best editor to use to create and modify input files. Regrettably, the Village network cannot be tested for this study, because of the limit in PC-LINKOD program capacity.

All three types of initial trip tables worked well, in terms of matching ground counts, P/A values, and total system trips. Level trip tables produced the best results in terms of link-to-link, P/A comparison, and conservation of trips, with the Beagan initial trip table a close second. The OD Factored table resulted in the worst trip table, but the results are still within an acceptable range. The sensitivity tests are necessary to determine the lowest number of iterations to be used while obtaining satisfactory results. The most important step when preparing the files is to make sure every field has a value, or else the program will read the input files incorrectly.

CHAPTER 4 FAST MATRIX CALIBRATION

Fast Matrix Calibration (FMC) was developed by Professor Rudi Hamerslag of the Technical University of Delft in the Netherlands. FMC is marketed by the consulting firm BGC of Deventer, the Netherlands. In the United States, the Urban Analysis Group (UAG) in Danville, CA is the distributor of the software. UAG is also the distributor of TranPlan, which is required in order to run FMC. TranPlan is a complete transportation modeling package capable of traditional four-step process and many other calculations. FMC is not a "stand-alone" program. It is an information minimizing model with elastic boundary conditions [Hamerslag, 1988]. In FMC, two elastic boundary conditions are used: screenline and zonal elasticities. Different constraint values can be assigned to individual or groups of the elastic conditions. When the constraints are fixed, 0 for zonal and 1 for screenline, FMC behaves very similar to THE, as this will be discussed further in detail starting in Section 4.4.6. FMC is designed to update an initial matrix given screenline constraints. Up to 450 screenlines can be used. The constraints are similar to the other two packages, in that FMC must produce a trip table as close to the initial trip table as possible, while satisfying the screenline conditions. As is TranPlan, FMC is coded in FORTRAN. The biggest difference between FMC and other packages tested in this study is that FMC is an add-on module for TranPlan.

4.1 Advantages

FMC shares a similar theoretical background with THE (Maximum Entropy/Minimum Information Methods), but with the added ability and flexibility to assign elasticities to an individual link value or an O-D value. The elasticities apply to zonal and link volumes. Each zonal cell and/or link volume can be given an elasticity that replaces the default values in the FMC batch file; detailed discussion will be presented in

Section 4.4.6. Because FMC is a module that works under TranPlan, users who are already familiar with TranPlan will need little time to become familiar with the software. Formats and notation are similar to those for TranPlan batch files.

Another distinctive advantage is the screen editor in TranPlan. Networks can be viewed, verified, and edited on-screen. This is extremely helpful when dealing with a large and complex network. FMC calculates trip tables based on screenline information. A screenline can contain a group of links or just one. For the tests, each screenline contained a single link, to allow better comparison with the other software tested. Due to the use of screenlines, a complete set of link count information is not required. (See Section 4.4.4 for more details.) However, more link information will produce a more accurate loading condition and contribute to a better calculated trip table. In any case, complete network data is required for network building.

4.2 Shortcomings

Drawbacks are few, and are mainly related to TranPlan procedures. Because many of FMC's features are included with a fully developed transportation modeling software, this results in more learning time for someone who is not familiar with TranPlan. The time needed to be proficient with FMC is longer than with THE and PC-LINKOD. More steps are required to prepare the input files for FMC, because TranPlan works in modules. Due to the ability to assign individual elasticity values, a vast amount of output could be generated that differs widely from one another. FMC users can choose many combinations of elasticities, which can cause the procedure to produce O-D tables that are sometimes very different. This sensitivity to elasticity values could be a disadvantage instead of advantage for the inexperienced user, because the best choice of elasticities may be difficult to determine. In addition, the TranPlan package requires a large amount of disk storage; it takes approximately 7 MB of disk storage besides the user data. However, it is possible to delete unnecessary files and just maintain the files essential to FMC and the O-D study. This can be done if the user is experienced with TranPlan and related procedures.

4.3 Things to Watch Out for

Because TranPlan/FMC is a complete transportation modeling package, the first step is make sure TranPlan is properly installed and is functioning correctly. A test network is included in the package to make the validation process simpler. Included with the user's manual are installation instructions on making the path modification in the "AUTOEXEC.BAT" file to make TranPlan accessible in every directory. The last installation remark is to be sure the FMC executable file is in the URBANSYS/TRANPLAN/ directory. Otherwise, TranPlan will not be able to locate the file.

An output status file (TRNPLN.OUT) is generated after each TranPlan module is executed. Included in this file are the batch file and information regarding to the most recent run. Any errors that occurred during the execution will be included in this file. One word of caution: This file is replaced by the next execution of TranPlan module. Make sure every step is error free and all the output is satisfactory before proceeding to the next step. Because all the input files are in ASCII format, any editor can be used. If a word processor is used, be sure to save the files in ASCII format instead of the native format. FMC requires a strict format for the input files. In a larger network, the use of computer programs to construct input files should be considered, so that formatting errors can be kept to a minimum.

The following excerpt from the FMC manual provides additional information in preparing input files for FMC:

> The algorithm used in FMC has as a condition that no double origin-destination pairs in a screen line may occur. An origin-destination-pair cannot go across the same screen line twice. A requirement is that all the screen lines are split up according to direction. Especially screen lines connected to slip roads could cause problems, therefore it is advisable to use mainly short screen lines [UAG, 1993].

4.4 How To Perform O-D Table Calculation

Six steps are required before the user can begin generating O-D tables using FMC. Some files are created in conjunction with TranPlan and others are created with the aid of an ASCII editor. This section will provide crucial information necessary for a successful run of FMC.

4.4.1 Highway Network Module

The network is created using the "$BUILD HIGHWAY NETWORK" module in TranPlan. The dollar sign "$" indicates a TranPlan batch file command. The batch file for the Gur 730 network is shown in Table 4.1. The network file that is generated as a result must be usable by other TranPlan procedures, so it is in binary format. The option "LARGE COORDINATES" is to allow the input field to correspond to state plane coordinates. This means only one node's data field would occupy a line. Without this option, three coordinate data points are stored per line. An ASCII version of the binary file can be obtained through the use of the "NETCARD" utility program included with TranPlan. This utility program can be used to verify network data if only the binary file is present.

Table 4.1 Building Highway Network Batch File

```
$BUILD HIGHWAY NETWORK
$FILE
     OUTPUT FILE = HWYNET, USER ID = $HWYNET.XXX$
$HEADERS
     GURS TEST NETWORK
$OPTIONS
   LARGE COORDINATES
$PARAMETERS
   NUMBER OF ZONES = 6
   MAXIMUM NODE = 15
   ERROR LIMIT = 5
$DATA
N    1        700       2100
N    2       2800       1400
N    3       2800        700
N    4       1400       2100
N    5          0        700
N    6       1400          0
N    7        700       1400
N    8        700        700
N    9       1400       1400
N   10       1400        700
N   11       2100       1400
N   12       2100        700
N   13        700          0
    7     18 700S60006000          510       1
   11     28 700S28002800         5240       1
   12     38 700S28002800         1090       1
    4     98 700S60006000         2460       1
    9     48 700S60006000         2050       1
    5     78 700S60006000         5130       1
    5     88 700S60006000          510       1
    5    138 350S14001400          110       1
    6    108 700S60006000         2050       1
    7     98 700S28002800         4910       1
    8    108 700S28002800          550       1
    9    108 700S60006000         1540       1
    9    118 700S28002800         5350       1
   10    128 700S28002800          980       1
   11    128 700S60006000          310       1
   13     68 700S14001400          110       1
    1     78 700S60006000          510       1
    8     58 700S60006000          510       1
    2    118 700S28002800         5240       1
    3    128 700S28002800         1090       1
   10     98 700S60006000         1540       1
   10     68 700S60006000         1750       1
   12    118 700S60006000          210       1
$END TP FUNCTION
```

4.4.2 Trip Table Module

An initial trip table is required input for FMC. The three types of initial trip tables are constructed within this module. TranPlan function "$BUILD TRIP TABLE" is used to generate the trip table. An example of this file can be seen in Table 4.2. Different trip tables are needed for the tests described in a later section and, with this module, the trip tables can be saved under different file names for later use. The input file for the batch file contains information on the cell location and the cell value. The data format is displayed in Table 4.3.

Table 4.2 Trip Table Building Batch File

```
$BUILD TRIP TABLE
$FILES
      INPUT FILE = SRVDATA, USER ID = $LEVEL.DAT$
      OUTPUT FILE = VOLUME, USER ID = $VOLUME.XXX$
$HEADERS

$OPTION
      PRINT TRIP ENDS
      SIMPLE
$PARAMETERS
      NUMBER OF ZONES = 6
      NUMBER OF PURPOSES = 1
$DATA
      TABLE 1 = ALL
$END TP FUNCTION
```

Table 4.3 SRVDATA File Format

Columns	Description
1-5	Origin Zone
6-10	Destination Zone
11-13	Trip Purpose Number
14-20	Number of Trips

4.4.3 Load Highway Selected Links Module

This module is used to indicate the links that may be used as screenlines in calculation for trip tables. The output file contains the loading history that FMC will later use in matching link volumes. Up to 450 links can be specified in a file [UAG, 1992]. This is the limiting element in the size of a network FMC that can evaluate and may be adequate for screenlines in Indiana. The batch file constructed for the Gur 730 network is shown in Table 4.4.

Table 4.4 Select History Batch File

```
$LOAD HIGHWAY SELECTED LINKS
$FILES
      INPUT FILE = HWYNET, USER ID = $HWYNET.XXX$
      INPUT FILE = HWYTRIP, USER ID = $VOLUME.XXX$
      OUTPUT FILE = LODHIST, USER ID = $LODHIST.XXX$
      OUTPUT FILE = SELHIST, USER ID = $SELHIST.XXX$
$HEADERS
      GURS TEST NETWORK
$OPTIONS
$PARAMETERS
      IMPEDANCE = TIME
      SELECTED PURPOSE = 1
      TWO WAY SELECTED LINKS = 4-9,9-10,10-6,12-11
      ONE WAY SELECTED LINKS = 5-7,5-13,7-1,7-9,8-10,13-6,9-11,10-12,
                                 5-8,11-2,12-3
$END TP FUNCTION
```

4.4.4 Build Assignment Evaluation File

The Assignment Evaluation (ASSEVA) file is required for FMC. It contains the screenline information pertinent for calculations such as screenline number and traffic counts. According to the FMC manual, a link count could be used for more than one screenline, up to a total of five screenlines [UAG, 1993]. The order of screenline numbers is not important, but the order helps in searching for a link when modification of a large file is required. ASSEVA is in ASCII format, so any text editor will handle this task. The links found in this file must appear in the "LOAD HIGHWAY SELECTED LINKS MODULE", but the reverse is not necessary. Strict format needs to be followed, as indicated in Table 4.5.

Table 4.5 ASSEVA File Format

Column(s)	Type	Description
1-5	I5	ANODE, junction of origin
6-10	I5	BNODE, junction of destination
11-14	A4*	Counting point
15	A1*	Direction
16-20	I5	Screen line number
21-28	I8	Counting value from ANODE to BNODE
34-59	S26*	Information

* These fields are not used by FMC. They provide additional information for the user.

4.4.5 Optional Flag Matrix

An optional flag matrix may be created to aid in the calculation of O-D tables. The dimension of the matrix is the same as the calculated matrix. This is a matrix that indicates the status of each cell: "1" means the cell contents cannot be changed, while "0" means the cell can be changed according to FMC. The flag matrix is only used when reliable and up-to-date zonal traffic information is known. It can be used in conjunction with zonal elasticities to further narrow down possible trip tables. This step is generally skipped, unless good information is known about travel between zones.

4.4.6 FMC Control File

The FMC batch file is the last file required. The necessary files should already be present if the above steps are followed (Sections 4.4.1-4.4.5). This file contains all the information essential to calculate trip tables. This file follows the standard TranPlan batch file format. The file names, such as input and output files, are declared in the first part of the control file. The manual indicates that the batch file is free format, as with other TranPlan batch files, but if error messages occur while there are no other apparent errors, be sure to check the margin spacing against the sample file that came with the software. With the current version, this study discovered that the margin spacing was the cause of errors: the margin provided by the "TAB" key contains two extra spaces. Use the "SPACE" key instead of the "TAB" key. This may be due to different keyboard and computer configurations, because the program was developed and written in the Netherlands.

The parameters declared in this file are number of iterations, default screenline elasticity, and default zonal elasticity. Individual screenline and zonal elasticities can be defined under the "$DATA" section apart from the default values. The closer to "1" the elasticity value becomes, the less adjustment it will allow to take place. A value close to "1" reflects a high degree of confidence in the data. For a network where the only data known is the link information, high values are assigned to screenline elasticities, and low values are assigned to zonal elasticities. In a situation where the reliability of the initial table is unknown, i.e., OD Factored and level trip tables, the default screenline elasticity is set at 1.0 while the default zonal elasticity is set at 0.0. This setting gives more weight on the link information instead of zonal information. In Section 4.5.1, the results will clarify the setting issues and both settings will be tested.

Table 4.6 FMC Batch File

```
$FAST MATRIX CALIBRATION
$FILES
      INPUT FILE = APRIOR, USER ID = $VOLUME.XXX$
      INPUT FILE = ASSEVA, USER ID = $GUR.TXT$
      INPUT FILE = SELHIST, USER ID = $SELHIST.XXX$
      OUTPUT FILE = FMCMAT, USER ID = $FMCMAT.YNG$
$HEADERS
      GUR'S TEST NETWORK
$OPTIONS
      NO AUTO GROWTH FACTOR
      NO BUCKET ROUNDING
$PARAMETERS
      NUMBER OF ITERATIONS = 100
      SCREENLINE CLOSURE = 1.0
      MINIMUM CHANGE = 0.1
      COEFFICIENT CLOSURE = 0.0001
      DEFAULT ZONAL ELASTICITY = 0.0
      DEFAULT SCREENLINE ELASTICITY = 1.0
$DATA
S   5   1.0
$END TP FUNCTION
```

4.5 Running FMC

The two networks are used in conjunction with the three initial trip tables discussed in Chapter 1. Level trip table cell values used as initial tables are 910 and 30 for the Gur 730 and Village networks, respectively. In Section 4.6, results of sensitivity tests of various level trip tables will be discussed. Two elasticity settings are used for each initial trip table. The notation in parentheses indicates the elasticity values. For example, "z0s1" indicates zonal elasticity of "0" and screenline elasticity of "1". Six trip tables are produced for the Gur 730 and Village networks; they are Tables 4.7-4.18.

Table 4.7 O-D Table for Gur 730 with Beagan Initial Matrix (z0s1)

FROM/TO	1	2	3	4	5	6	TOTAL
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0
4	0	619	292	0	0	1465	2376
5	499	4018	392	495	0	197	5601
6	0	203	279	1505	0	0	1987
TOTAL	499	4840	963	2000	0	1662	**9964**

Table 4.8 O-D Table for Gur 730 with Beagan Initial Matrix (z1s1)

FROM/TO	1	2	3	4	5	6	TOTAL
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0
4	0	613	294	0	0	1478	2385
5	499	4013	393	497	0	198	5600
6	0	202	287	1504	0	0	1993
TOTAL	499	4828	974	2001	0	1676	**9978**

Table 4.9 O-D Table for Gur 730 with 910 Level Initial Matrix (z0s1)

FROM/TO	1	2	3	4	5	6	TOTAL
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0
4	0	725	491	0	0	1227	2443
5	503	2927	175	1547	0	418	5570
6	0	1213	294	480	0	0	1987
TOTAL	503	4865	960	2027	0	1645	**10000**

Table 4.10 O-D Table for Gur 730 with 910 Level Initial Matrix (z1s1)

FROM/TO	1	2	3	4	5	6	TOTAL
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0
4	0	622	579	0	0	1315	2516
5	684	2509	185	1481	0	382	5241
6	0	1099	775	496	0	0	2370
TOTAL	684	4230	1539	1977	0	1697	**10127**

Table 4.11 O-D Table for Gur 730 with OD Factored Initial Matrix (z0s1)

FROM/TO	1	2	3	4	5	6	TOTAL
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0
4	0	622	579	0	0	1315	2516
5	684	2509	185	1481	0	382	5241
6	0	1099	775	496	0	0	2370
TOTAL	684	4230	1539	1977	0	1697	**10127**

Table 4.12 O-D Table for Gur 730 with OD Factored Initial Matrix (z1s1)

FROM/TO	1	2	3	4	5	6	TOTAL
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0
4	12	655	475	0	0	1268	2410
5	484	3036	199	1469	0	398	5586
6	23	1150	298	539	0	0	2010
TOTAL	519	4841	972	2008	0	1666	**10006**

Table 4.13 O-D Table for the Village Network with Observed Initial Matrix (z0s1)

FROM/TO	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	TOTAL
1	0	3	21	59	37	18	5	162	76	371	15	36	2	13	93	911
2	13	0	3	0	0	1	0	1	18	109	1	0	0	0	0	146
3	155	0	0	31	18	27	3	78	289	11	35	37	3	24	50	761
4	10	0	45	0	2	2	0	2	0	105	0	6	0	2	4	178
5	16	0	72	4	0	4	0	3	0	166	0	9	0	5	7	286
6	1	0	85	5	3	0	0	0	0	188	0	0	0	6	9	297
7	0	0	10	0	0	0	0	0	227	57	41	0	0	0	1	336
8	140	0	9	11	7	4	1	0	30	67	4	8	0	4	17	302
9	18	7	514	96	56	1	56	10	0	39	134	5	13	1	55	1005
10	892	89	56	8	4	37	8	134	103	0	30	92	3	29	15	1500
11	3	0	34	7	4	0	0	1	41	6	0	0	0	0	5	101
12	7	3	1	22	9	0	0	2	4	203	0	0	0	0	0	251
13	5	1	114	14	7	0	7	2	93	15	18	1	0	0	11	288
14	1	0	62	2	1	8	0	0	0	170	0	0	0	0	16	260
15	19	0	83	6	2	5	0	4	31	2	4	5	0	6	0	167
TOTAL	1280	103	1109	265	150	107	80	399	912	1509	282	199	21	90	283	6789

Table 4.14 O-D Table for the Village Network with Observed Matrix (z1s1)

FROM/TO	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	TOTA
1	0	2	11	57	35	21	5	170	76	368	13	32	2	13	96	901
2	14	0	3	0	0	1	0	1	16	112	0	0	0	0	0	147
3	157	0	0	28	17	20	1	77	295	11	29	34	2	25	49	745
4	11	0	44	0	1	1	0	2	0	106	0	5	0	2	4	176
5	17	0	71	4	0	3	0	4	0	169	0	8	0	5	7	288
6	1	0	82	4	3	0	0	0	0	191	0	0	0	6	8	295
7	0	0	7	0	0	0	0	0	237	47	26	0	0	0	0	317
8	145	0	4	10	7	4	1	0	30	65	3	7	0	4	17	297
9	18	6	524	103	60	2	56	10	0	41	86	4	12	1	56	979
10	903	86	57	7	4	46	8	133	107	0	25	81	3	30	16	1506
11	2	0	33	7	4	0	0	1	42	6	0	0	0	0	4	99
12	9	3	2	21	9	0	0	2	3	201	0	0	0	0	0	250
13	4	1	109	14	7	0	6	2	90	14	10	1	0	0	10	268
14	1	0	63	2	1	7	0	0	0	170	0	0	0	0	16	260
15	21	0	84	5	2	4	0	5	32	2	4	5	0	6	0	170
TOTAL	1303	98	1094	262	150	109	77	407	928	1503	196	177	19	92	283	6698

Table 4.15 O-D Table for the Village Network with Level Initial Matrix (z0s1)

ROM/TO	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	TOTAL
1	0	2	42	100	48	23	8	110	75	297	25	50	4	21	102	907
2	8	0	3	0	0	1	0	1	14	116	2	0	0	1	0	146
3	284	0	0	22	10	48	3	16	204	10	63	43	7	39	22	771
4	8	0	50	0	0	1	0	1	0	116	0	4	1	1	0	182
5	16	0	93	1	0	2	0	1	0	165	0	7	4	2	1	292
6	1	0	110	1	0	0	0	0	0	180	0	0	5	2	1	300
7	0	0	11	0	0	0	0	0	268	51	11	0	0	0	0	341
8	123	0	3	9	4	8	3	0	33	77	10	16	1	7	10	304
9	21	7	406	88	59	2	60	8	0	44	204	4	5	1	105	1014
10	779	92	68	8	5	19	3	256	109	0	22	71	1	16	8	1457
11	3	1	63	5	3	0	0	1	12	4	0	0	0	0	12	104
12	6	0	2	17	11	0	0	1	4	215	0	0	0	0	0	256
13	7	2	115	16	11	0	3	3	91	11	3	1	0	0	28	291
14	1	0	81	1	0	3	0	0	0	177	0	0	0	0	1	264
15	10	0	63	0	0	1	0	1	70	2	16	5	1	1	0	170
TOTAL	1267	104	1110	268	151	108	80	399	880	1465	356	201	29	91	290	6799

Table 4.16 O-D Table for the Village Network with Level Initial Matrix (z1s1)

FROM/TO	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	TOTAL
1	0	16	0	89	74	23	13	30	78	49	52	132	5	50	54	665
2	64	0	25	5	4	3	1	17	28	97	13	2	0	10	3	272
3	59	1	0	36	30	93	23	9	118	2	77	39	5	72	22	586
4	5	0	40	0	3	14	2	1	1	132	0	12	89	10	2	311
5	5	0	46	6	0	18	3	1	1	141	0	13	117	13	3	367
6	1	1	51	6	5	0	3	0	1	149	0	0	137	15	3	372
7	1	0	18	2	1	6	0	0	178	85	60	0	26	4	1	382
8	49	5	0	28	23	14	8	0	52	26	33	76	3	30	17	364
9	9	11	237	57	51	2	130	5	0	17	95	4	2	7	114	741
10	613	132	22	9	8	0	0	326	1	0	0	0	0	0	6	1117
11	4	4	117	18	16	0	16	2	34	7	0	1	0	1	49	269
12	33	79	14	25	22	1	0	9	10	134	4	0	0	2	2	335
13	6	6	127	25	23	1	29	3	53	10	12	2	0	3	59	359
14	1	0	83	12	9	52	9	0	0	179	0	0	0	0	6	351
15	8	0	72	9	7	29	5	2	85	1	49	18	2	21	0	308
TOTAL	858	255	852	327	276	256	242	405	640	1029	395	299	386	238	341	6799

Table 4.17 O-D Table for the Village Network with OD Factored Initial Matrix (z0s1)

FROM/TO	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	TOTAL
1	0	3	28	68	39	16	4	139	89	352	14	38	1	14	102	907
2	9	0	2	0	0	2	0	2	11	114	2	1	0	2	0	145
3	226	0	0	26	15	31	2	44	254	10	46	39	4	27	39	763
4	9	0	48	0	1	3	0	2	0	106	0	6	0	2	3	180
5	14	0	76	3	0	5	0	3	0	171	0	8	1	5	5	291
6	1	0	92	3	2	0	0	0	0	188	0	0	1	6	6	299
7	0	0	9	0	0	0	0	0	225	54	46	0	0	0	0	334
8	131	1	5	14	8	4	1	0	22	80	3	9	0	4	20	302
9	29	3	488	89	52	1	57	7	0	48	133	3	14	1	78	1003
10	827	92	74	5	3	27	5	197	126	0	19	90	1	25	7	1498
11	2	0	39	7	3	0	4	1	35	4	0	0	0	0	6	101
12	6	2	2	25	14	0	0	1	2	200	0	0	0	0	0	252
13	7	1	98	18	10	0	7	2	96	12	17	1	0	0	17	286
14	1	0	72	3	2	13	0	0	0	167	0	0	0	0	5	263
15	13	0	73	3	2	6	0	3	48	1	8	8	0	4	0	169
TOTAL	1275	102	1106	264	151	108	80	401	908	1507	288	203	22	90	288	6793

Table 4.18 O-D Table for the Village Network with OD Factored Initial Matrix (z1s1)

FROM/TO	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	TOTAL
1	0	2	14	67	39	19	4	148	90	350	12	35	1	15	106	902
2	10	0	2	0	0	2	0	2	10	117	1	0	0	2	0	146
3	229	0	0	24	13	25	1	42	262	10	39	35	3	27	37	747
4	10	0	47	0	1	2	0	2	0	107	0	5	0	2	3	179
5	16	0	75	2	0	3	0	3	0	173	0	7	0	4	4	287
6	1	0	90	3	2	0	0	0	0	190	0	0	0	5	5	296
7	0	0	6	0	0	0	0	0	238	44	28	0	0	0	0	316
8	137	0	2	13	7	4	1	0	22	77	3	8	0	4	19	297
9	29	3	500	96	56	1	57	7	0	50	82	2	14	1	78	976
10	839	89	74	5	3	36	4	194	129	0	15	78	1	27	7	1501
11	2	0	38	7	4	0	3	1	35	3	0	0	0	0	6	99
12	8	2	2	25	14	0	0	2	2	198	0	0	0	0	0	253
13	7	1	94	17	10	0	6	2	94	11	9	0	0	0	16	267
14	1	0	73	2	1	11	0	0	0	167	0	0	0	0	4	259
15	16	0	73	3	2	5	0	3	49	1	6	7	0	4	0	169
TOTAL	1305	97	1090	264	152	108	76	406	931	1498	195	177	19	91	285	6694

4.5.1 Findings

The first inspection is to determine how well the calculated results compare with known data. Tabulated results of P/A and link-to-link comparisons are shown in Tables 4.19 and 4.20. In the Gur 730 network, Beagan and OD Factored tables performed well with the "z1s1" setting, while a level trip table produced better results with the "z0s1" setting. These results demonstrate that an OD Factored initial table provided enough information to estimate a useful trip table. In the Village network, P/A results exhibit a similar trend with the same elasticity settings as with Gur 730, while a link-to-link comparison shows that the "z0s1" setting performed slightly better. With both networks, when a level trip table is used, zonal elasticity should receive a zero value in FMC. A level trip table did not provide sufficient information.

Table 4.19 Production and Attraction Comparison (FMC)

	Production and Attraction (%RMSE)		
Network	Beagan/Observed*	Level	OD Factored
Gur 730 Network (z0s1)	2.032%	3.163%	9.633%
Gur 730 Network (z1s1)	1.360%	27.26%	1.885%
Village Network (z0s1)	7.419%	10.07%	7.617%
Village Network (z1s1)	4.766%	47.40%	4.794%

*Beagan for Gur 730 and observed trip table for the Village network

Table 4.20 Link-To-Link Comparisons (FMC)

	Link-To-Link Comparisons (%RMSE)		
Network	Beagan/Observed	Level	OD Factored
Gur 730 Network (z0s1)	1.497%	1.729%	1.643%
Gur 730 Network (z1s1)	1.565%	16.18%	1.579%
Village Network (z0s1)	24.30%	24.38%	24.25%
Village Network (z1s1)	24.49%	32.56%	24.42%

In the next comparison, final calculated trip tables are compared with known possible solutions. Table 4.21 has a tabulation of the results. Only Gur 730 with the Beagan initial table had a better match when the zonal elasticity value is one. With the Village network, OD Factored initial table produced slightly improved results over the other two initial trip tables. In FMC, the zonal elasticity value tells the program the degree to which the trip cells can be varied. A value of one indicates a minimum amount of adjustment is desired.

Table 4.21 Initial Trip Table Comparison (FMC)

	Trip Table Comparison (%RMSE)		
Network	Beagan/Observed	Level	OD Factored
Gur 730 Network (z0s1)	1.674%	70.66%	77.44%
Gur 730 Network (z1s1)	1.105%	77.45%	65.18%
Village Network (z0s1)	143.71%	149.66%	175.33%
Village Network (z1s1)	145.69%	174.32%	141.46%

Next comparison is to see how different each of the calculated trip tables compares with others. Table 4.22 summarized the settings used in the Gur 730 network. Table 4.23 has a comparison of the two elasticity settings with the same level trip table (z0s1) used for both sets. In Gur 730, OD Factored and level trip tables produced matrices that are closer matches than when compared with Beagan trip table. With the Village network, OD Factored and observed seed tables produced matrices that resemble each other more closely than they resemble the matrix based on a level trip table.

Table 4.22 Gur 730 Network Final Trip Table Analysis (FMC)

Gur 730 Network	%RMSE
Beagan (z1s1) vs. Level (z0s1)	70.85%
Level (z0s1) vs. OD Factored (z1s1)	6.141%
OD Factored (z1s1) vs. Beagan (z1s1)	65.38%

Table 4.23 Village Network Final Trip Table Analysis (FMC)

Village Network (z0s1)	(%RMSE)
Observed vs. Level	71.13%
Level vs. OD Factored	45.41%
OD Factored vs. Observed	33.24%
Village Network (z1s1)	
Observed vs. Level (z0s1)	76.50%
Level (z0s1) vs. OD Factored	52.81%
OD Factored vs. Observed	32.74%

4.6 Sensitivity Analysis

Various parameters are tested to determine the efficiency of FMC. These include number of iterations, level trip table, conservation of trips, and use of known initial trip tables.

4.6.1 Number of Iterations

The number of iterations required depends on the complexity of the network and the information the initial trip table provides. Many test trials were needed to determine a suitable recommendation for the number of iterations. Generally it is recommended to allow the calculations to stabilize before no apparent improvement is imperative and then stop the calculation. In the FMC batch file, the parameter governing convergence is the

"MINIMUM CHANGE". It is set at 0.1 because trip values in integer form are reported by FMC. In any case, the number of iterations is set to 100 in case an O-D calculation is caught in a loop. In the tests done on Gur 730, all calculations took fewer than 60 iterations with level trip tables; Beagan's initial trip table took less than 10 iterations. A plot of error versus number of iterations with three level trip tables is shown in Figure 4.1. In the Village network, three level trip tables are used for the plot, as shown in Figure 4.2. Smooth lines illustrate good convergence quality with virtually no fluctuations. The total system trips of level trip tables determine where the error convergence starts; underestimated level trip table will have reported difference less than the system trips. When level trip tables have are based on total trips in the network, 910 and 30 for Gur 730 and the Village networks, respectively, the error curves begin at the bottom and stay between the other two curves, as shown in the two plots.

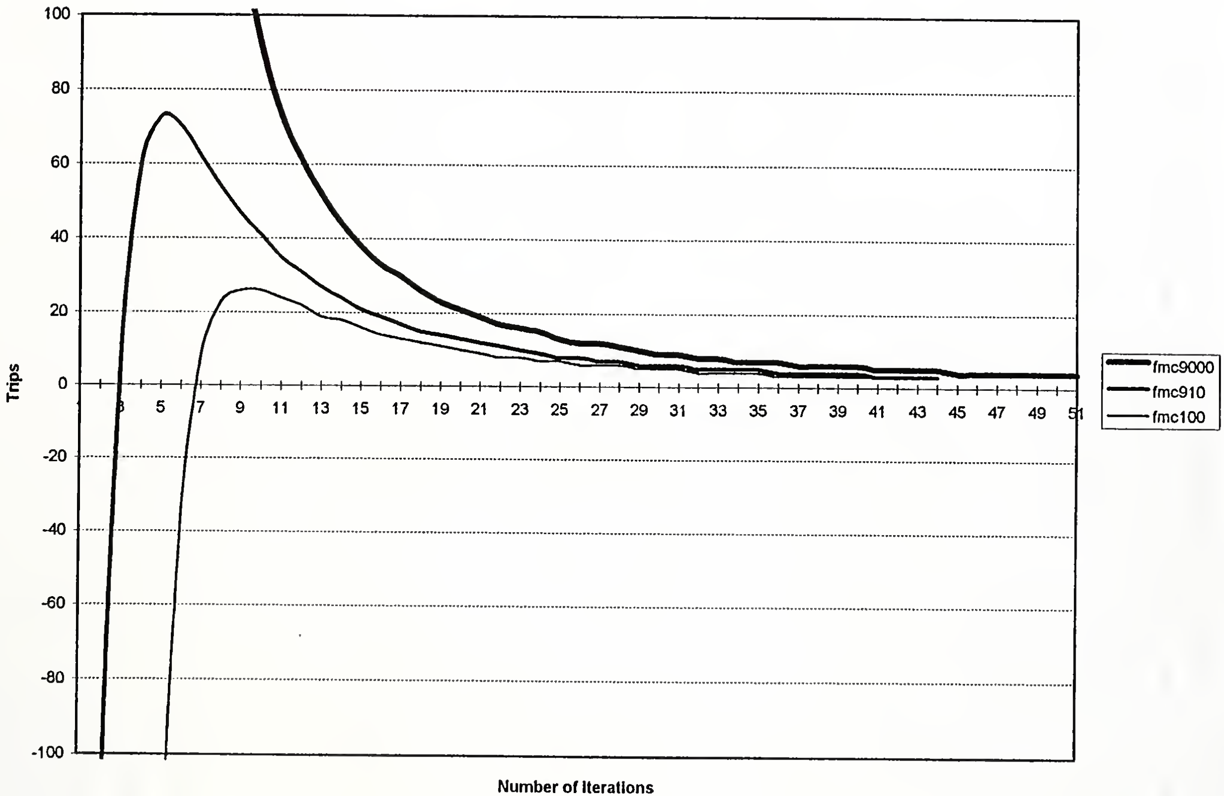

Figure 4.1 Level Trip Table Iteration Analysis with Gur 730 Network

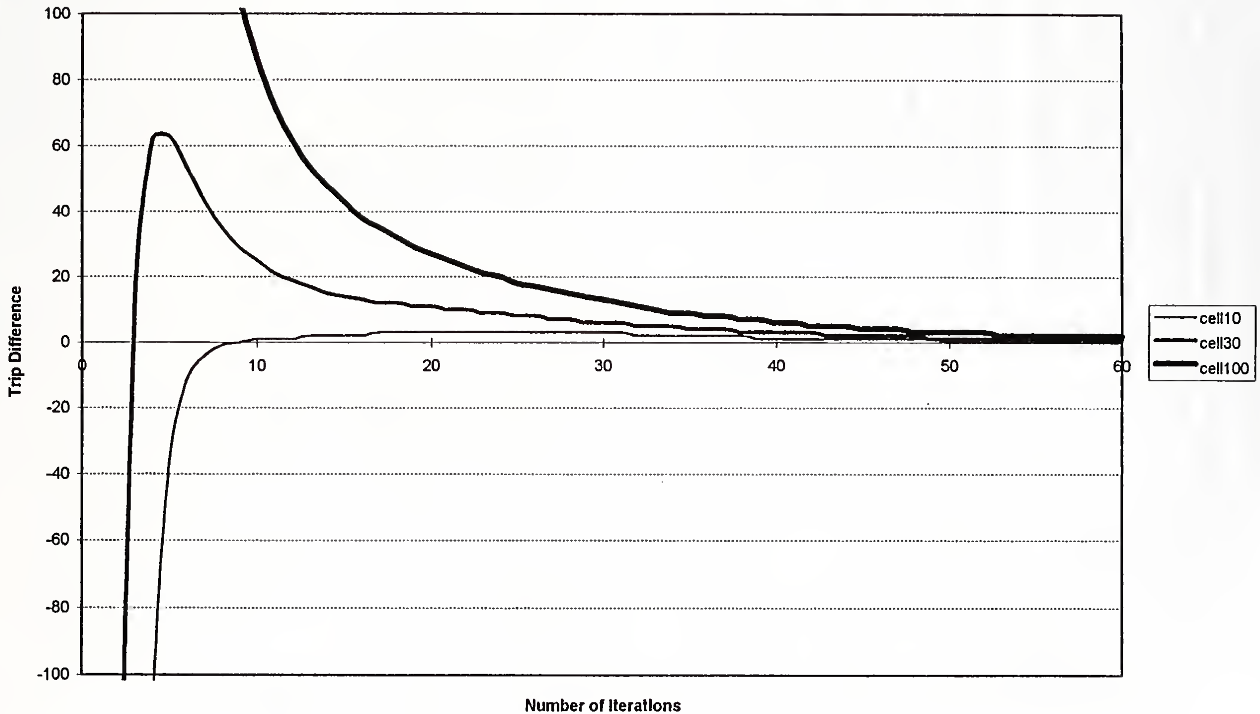

Figure 4.2 Level Trip Table Iteration Analysis with Village Network

4.6.2 Level Trip Table Sensitivity Analysis

When there is no prior information regarding the O-D matrix, one needs to be concerned with what initial table will be used in the calculation. A level trip table is accepted as one of many alternatives in place of an old trip table. What cell value can be used and what difference is there between a small and a large level value? In this section, six different level cell values are used in Gur 730 and three level cell values are used in the Village network. The values are selected to represent the total trip on the networks. Some are lower than the network trips and others are at that level and one is greater than the system trips. Tables 4.24 and 4.25 are the comparison between level trip tables for both test networks. In the second column, the matrices are compared with the results from using the level trip table of 910 and 30, for Gur 730 and the Village networks, respectively. The third column is the P/A comparison used in this study. As seen from both tables, no major difference exists among level trip tables. In addition, their performance is similar in terms of P/A values.

Table 4.24 Level Trip Table Comparisons for Gur 730 Network

Level Cell Value	VS. 910 %RMSE	P/A %RMSE
1	2.09%	3.38%
10	2.07%	3.38%
100	1.70%	3.35%
500	0.65%	3.23%
910	n/a	3.16%
9000	2.10%	2.90%

Table 4.25 Level Trip Table Comparisons for Village Network

Level Cell Value	VS. 30 %RMSE	P/A %RMSE
10	2.05%	9.91%
30	n/a	10.1%
100	2.91%	10.1%

4.6.3 Does FMC Create or Destroy Trips?

The tendency of software to create or destroy trips is not desirable. Conservation of total system trips is a concept important to O-D studies. From the calculations performed in Section 4.5, the percentage differences of total number of trips and initial trip tables are summarized in Table 4.26. With Gur 730, the results are similar to P/A and link-to-link comparisons. Beagan and O-D produced closer matches using the "z1s1" setting and a level trip table using "z0s1" setting. With the Village network, the results are mixed: closer matched system trips are obtained with Beagan and level "z1s1" and OD Factored "z0s1". The value increases with cell value but not at a significant rate.

In Tables 4.27 and 4.28, the comparisons of level trip tables in percentages are listed. With Gur 730, as the level trip cell value approaches 910, the better the calculated trip table conserved total system trips. The Village network showed a similar trend, while an underestimated level trip table produced the best result. This illustrates when using FMC, a level trip cell should consist of a value that should add up to the total system trips.

Table 4.26 Total System Trips Comparison (FMC)

	% Difference Between System and Calculated Trips*		
Network	Beagan/Observed	Level	OD Factored
Gur 730 Network (z0s1)	0.34%	0.00%	-2.41%
Gur 730 Network (z1s1)	0.22%	-1.27%	-0.06%
Village Network (z0s1)	-2.07	-2.23%	-2.14%
Village Network (z1s1)	-0.71%	-0.68%	-2.33%

*Negative = Overestimate

Table 4.27 Gur 730 Total System Trips

Initial Trip Table	% Difference*
Level 1	0.13%
Level 10	0.12%
Level 100	0.10%
Level 500	0.04%
Level 910	0.00%
Level 9000	-0.16%

*Negative = Overestimate

Table 4.28 Village Network Total System Trips

Initial Trip Table	% Difference*
Level 10	-2.12%
Level 30	-2.23%
Level 100	-2.41%

*Negative = Overestimate

4.7 Conclusion

FMC worked well with the test networks. Because FMC functions as a module within TranPlan, the learning time is increased. The modular design permits mistakes to be detected at any step. The ability of FMC to use information if the form of elasticities is an advantage, with the degree of information reliability be determined by the user. In the case with small- and medium-sized networks, complete set of links should be used as screenlines. With a larger network, such as the Indiana network, careful consideration will be required before the screenlines are assigned.

FMC can be easily operated once the necessary files are constructed. The startup time is longer, because it takes time to absorb the features embedded in TranPlan and FMC. The additional valuable feature that TranPlan provides is the on-screen editor. The network can be viewed and modified on-screen, which can eliminate a lot of work when dealing with a large network. Extra attention is needed when using the modular design of TranPlan, because steps may be missed during the preparatory phase before generating O-D tables. The batch files are cumbersome at first, but they turned out to be a beneficial feature, because every step can be verified before advancing to the next step.

As shown with the Gur 730 network tests, the OD Factored table provided sufficient information to have the zonal elasticity of "1" used instead of using "0" with a level initial trip table. On both test networks, FMC produced satisfactory results with the three types of initial trip tables. When level initial trip tables are used, a zonal elasticity of zero is recommended. The table does not provide any information, except to serve as a starting point. Tests shown little difference in the outcome between different cell values. The conservation of trips improves slightly as the total trips in the level trip table approach total system trips. In any case, conservation of trips is observed in FMC with the three types of initial trip table.

CHAPTER 5 SELECTION AND RECOMMENDATION

In Chapters 2-4, the packages THE, PC-LINKOD, and FMC have been tested and evaluated on the basis of data preparation, ease of use, and their features. Calculated trip tables are also presented in those chapters. The results from each package are summarized in parallel in this chapter to rank their reliability, ease of use, and other features. This chapter will discuss the advantages and disadvantages of each package. Section 5.1 will be a summary of statistics from Chapters 2-4, this will be the comparison of the reliability of calculated trip tables. The capacity of each package will be compared in Section 5.2. These two attributes are the most important, because accurate results and adequate capacity are essential to the statewide network study. Other areas to be discussed later in the chapter include the ease of implementation, operation, and flexibility of the programs. A summary table is presented in Section 5.6 with a point system to quantify the comparison.

5.1 Reliability of Results

This is perhaps the most important part of any software: Reliability. No matter how easy a package is to run or the number of features it has, the focus is on the package to deliver dependable and reliable results. This section investigates several scenarios in which O-D tables are produced. Because all the packages produced satisfactory results, they are compared with each other to find the most accurate package. Three categories are used in the evaluation: goodness of fit, ability to benefit from initial matrix, and conservation of system trips. These results are shown in Table 5.1. In the reliability category ranking process, the Gur 730 and Village networks are separated to give PC-LINKOD a fair comparison. Because PC-LINKOD could not be tested on the Village network, a separate analysis is made without the test results from the Village network. In using FMC, results from the "z1s1" setting is presented with initial trip tables based on Beagan and OD Factor methods, while "z0s1" is used with a level initial trip table.

Table 5.1 Reliability Comparison of O-D Packages

Category	THE (Original)	THE (Modified)	PC-LINKOD	FMC
Goodness of Fit	%RMSE	%RMSE	%RMSE	%RMSE
Gur 730 Network				
P/A, (Beagan Matrix)	0.106	0.662	0.717	1.360
Link-to-Link	0.3626	1.4905	0.4117	1.565
P/A, (Level Matrix)	0.113	0.591	0.678	3.163
Link-to-Link	0.1495	1.4423	0.3259	1.729
P/A, (OD Factored Matrix)	0.165	0.634	9.164	1.885
Link-to-Link	0.1420	1.4945	7.2946	1.579
Village Network				
P/A, (Observed Matrix)	4.353	n/a	n/a	4.766
Link-to-Link	18.98	n/a	n/a	24.49
P/A, (Level Matrix)	4.766	n/a	n/a	10.07
Link-to-Link	18.80	n/a	n/a	24.38
P/A, (OD Factored Matrix)	4.312	n/a	n/a	4.794
Link-to-Link	19.00	n/a	n/a	24.42
Mimicking				
Gur 730 Network				
Beagan Matrix	7.68	7.76	7.00	1.105
OD Factored Matrix	82.07	7.79	75.23	65.18
Village Network				
Observed Matrix	179.10	n/a	n/a	145.69
OD Factored Matrix	173.12	n/a	n/a	141.46
Trip Conservation	%Difference	%Difference	%Difference	%Difference
Gur 730 Network				
Beagan Matrix	-0.03	0.17	0.31	0.22
Level Matrix	0.01	0.08	0.18	0
OD Factored Matrix	-0.04	0.12	-2.59	-0.06
Village Network				
Observed Matrix	-2.646	n/a	n/a	-0.71
Level Matrix	-3.398	n/a	n/a	-2.41
OD Factored Matrix	-2.932	n/a	n/a	-2.23

In the goodness of fit category, two measures are used: production and attraction (P/A) and link-to-link measures (LTL). This determines if the results are valid when compared with known information. For Gur 730, THE is the best of the three packages, producing nearly identical P/A and link loading values as the input network information. PC-LINKOD produced good results with Beagan and level trip tables, but returned erratic results with the OD Factored matrix. With the Village network, THE produced better results than FMC.

The second category involves the ability of the software to benefit from prior information. This is to determine, if and when a reasonable O-D table is available as the initial trip table, the capability of the software to employ this information. In this comparison, a smaller value denotes less change, meaning more utilization of the initial trip table. With the Gur 730 network, FMC had a close match with the Beagan matrix (1.105 PRMSE) while other two had PRMSE of more than 7%. The large error measures with the OD Factored table is because the Beagan solution was not unique. (See Section 1.2.1.) On the Village network, FMC achieved a better matching of initial trip tables, with OD Factored producing slightly better results than the observed trip table.

The last comparison is the conservation of total system trips. Preserving the original number of trips can be one indication of how well the calculated tables are produced. If the sum of estimated table entries exceed or fall short of the total observed trips by a large margin, then the software is questionable. With a level trip table, FMC was able to preserve 100% of the trips in Gur 730. THE, on the other hand, overestimated and underestimated with two versions of the network based on Beagan and OD Factored tables. In the Village network, FMC produced closer values in terms of total system trips with all three initial tables than THE.

FMC is produced superior results in both test networks. THE came in second in the reliability test. FMC performed well in mimicking initial trip tables and conserving system trips. PC-LINKOD best utilized the initial trip table, but produced inconsistent results in the goodness of fit and conservation tests.

5.2 Capacity of Package

The next important characteristic of O-D estimation software is its capacity. This study deals with a statewide network, so the network data would consist of a large number of nodes and links. Inadequate software capacity should not be the reason a network is simplified. A network can be properly simplified only as long as the characteristics of the network are preserved. Expansion of a network may be desired to accommodate new information or details important to a study. New zones or features may be added later, so it is important for the software to have the capacity for expansion.

In this comparison, FMC has the largest capacity, handling 3000 zones and 16,000 nodes, with each node capable of having 31 connectors [UAG, 1992]. However, only 450 screenlines can be used in the O-D calculation. THE has the next largest capacity: 300 zones, 2000 nodes, and 3000 links [Bromage, 1991]. However, the O-D module of THE can handle 300 nodes and 500 links. PC-LINKOD has the smallest capacity, handling only 27 zones, 155 nodes, and 100 links [O'Neill, 1992], but a C version of the program may be available soon to accommodate larger network. The current version is meant to be a test program for small networks. Table 5.2 shows the summary of the capacity of each software.

Table 5.2 Software Capacity Summary

	THE	PC-LINKOD	FMC
Zones	300	27	3000
Nodes	300	155	16000
Links	500	100	node dependent
Screenlines	n/a	n/a	450
Node Connectors	4	n/a	31

5.3 Ease of Implementation

PC-LINKOD (Chapter 3) is the easiest of the three packages to understand, because it is designed especially for O-D calculations. The procedures are much simpler and straightforward than the other packages. Three files are required as input: the network, initial trip table, and volume/capacity function files. They can be easily constructed with a spreadsheet program. Due to their modular designs, both THE and FMC require many steps to prepare their input files. With THE (Chapter 2), two input files are constructed with its internal editor; this creates a long delay when dealing with a large network's data. Many steps are required to prepare the necessary files to run the O-D calculation. Similarly, FMC (Chapter 4) is a module within TranPlan. This also means various steps are required to prepare input files before running FMC. It takes only a small amount of time before the user is proficient with PC-LINKOD. Sample input files are also included to help in learning the program. FMC is the hardest to learn, because preparation of the files requires the user to fully understand the TranPlan package. A sample file is also included with the package to speed up the learning process.

Documentation and staff support are very important in successfully running the programs. Generally the vendors and the developers know more about their own products than anyone else. All three packages have sufficient documentation to get started. FMC is the most complex software and the literature is barely sufficient. Many calls to the vendors have solved some problems. THE and FMC are commercial software, so staff support is available. PC-LINKOD on the other hand is an academic/research software in its current forms, so any response would involve prevailing upon Professor O'Neill.

5.4 Ease of Operation

Also of importance in an evaluation of the packages is their ease of operation. Does the software allow easy modifications of network data? Does the software have error checking capabilities, so mistakes in coding of networks can be discovered in the beginning instead of later, when erroneous O-D results are revealed? Lastly, does the software allow easy access to obtain results? Often the results are available, but in an unreasonable format.

FMC and PC-LINKOD are constructed with an ASCII editor, so the modification ability depends on the editor itself. As stated earlier, consider using a database or spreadsheet program when dealing with a large network. Another technique for dealing with large networks is to write specific programs for the strict format requirement in the case of FMC. THE's editor is easy to use but very limited in its functions: only one line is seen and edited at a time. This will be time consuming when constructing a large network; each line of data had to be called, searched, and edited. No copy or paste feature is available here. THE is not well suited to a large network, because of its limited editing capabilities.

Both THE and FMC have their own features built in to detect possible coding errors. Examples of common errors are links without connections or no access to/from a zone. THE warns the user through the output to printer and FMC denotes errors in status output file when possible errors are detected. This should be a mandatory feature embedded in O-D packages. THE has an option to halt the computation when errors are detected. FMC has a different feature, assigning a limit on errors that can be allowed before it is halted as well. PC-LINKOD, on the other hand, does not have any error checking feature. A network will need to be manually checked and it can be time consuming.

PC-LINKOD and FMC make it easy to obtain usable results in hard copy form because they are coded in ASCII format. With FMC, internal output files in binary format are converted into ASCII format with supplied utility programs. THE is a little tricky, because it has its own module for outputting data. Some modules allow partial printing of the file such as network data and others can only produce a complete report every time it is printed. This can be bothersome because unwanted output is generated.

FMC has the most functional features in the operation category, most of which are included with the TranPlan package. PC-LINKOD is more efficient in modifying files while THE and FMC has the most useful error checking ability.

5.5 Flexibility

All three packages have the same capability to assign the number of iterations and the convergence criteria for trip table calculations. FMC has additional features to utilize zonal and link information as discussed in Chapter 4; these features are zonal and link volume elasticities. Default elasticities are assigned with the option to assign individual values. These values are between "0" and "1". The closer the value is to "1", the more reliable the piece of information is thought to be. For example, when the network traffic volumes on links are highly reliable, a value of "1" is assigned. If the data source is questionable, then a lower value can be assigned. This is an advantage FMC has over the other two packages.

5.6 Conclusion

A score system has been devised to quantify the ranking results: 10 is given to the best package in each category, 9 for the second, and 8 for the third. If two packages tie for the first, the third package will receive 8 points. The summary table can be seen in Table 5.2. Two point scales are shown in the table, with and without the Village network comparison. This is to give PC-LINKOD a fair chance in competing for the selection. The last column declares the sections in which the comparisons are made. Based on the category comparisons, FMC is the choice to be used for the statewide O-D study. FMC scored 87 out of 90 point in the first tally and 116 out of 120 points for the complete tabulation. THE came in second with 82 and 110 points. PC-LINKOD came in last with only 52 points.

FMC's capacity and flexibility are much greater than the other two, while its performance is similar and sometimes better than THE and PC-LINKOD. It is the hardest to learn, but the additional benefits coming from TranPlan should easily compensate for the extra work. TranPlan has a modular structure, so each individual step can be checked and verified before proceeding to the next step. This procedure prevents mistakes from accumulating into a fatal error by making sure every step's output is valid for use in the next module.

Table 5.3 Summary of Software Evaluation

Category	THE	PC-LINKOD	FMC	Section
Gur 730 Network				
Goodness of Fit	10	9	9	5.1
Mimicking	8	10	10	5.1
Trip Conservation	10	8	10	5.1
Village Network				
Goodness of Fit	10	n/a	9	5.1
Mimicking	9	n/a	10	5.1
Trip Conservation	9	n/a	10	5.1
Capacity	9	8	10	5.2
Implementation	9	10	8	5.3
Doc/Staff Support	10	8	10	5.3
Operation	9	9	10	5.4
Error Checking	9	8 (no)	10	5.4
Flexibility	8	9	10	5.5
TOTAL* (90)	82	52	87	
	91.1%	57.8%	96.7%	
TOTAL** (120)	110	n/a	116	
	91.7%	n/a	96.7%	

* This summation does not include the Village network's statistics.

** This is the total comparison.

CHAPTER 6 THE INDIANA NETWORK

An accurate network is necessary for the estimation of an O-D table, regardless of the software packages chosen. For this study, a basic statewide network was acquired from Professor Black of Indiana University [Black, 1993]. The network was being used by IU researchers in a commodity flow study. A goal at the time was to have a common network for both groups, such that Indiana DOT could use, maintain, and distribute the network to anyone working on a statewide transportation problem. Although the intent was worthwhile, minor modifications to the network had to be made to satisfy the requirements of this project. The basic network was constructed with commodity flow in mind, while leaving out details that are vital for other studies. However, the finished network conforms with the national highway system, with updated link information added as it becomes available. This chapter is written with the assumption that the reader has some knowledge of computer programming and Geographic Information Systems (GIS).

6.1 Traffic Data

The O-D study is done on a 24-hour basis, which is consistent with a principal data source, the *Highway Traffic Statistics 1991 Handbook* [INDOT, 1991]. Some modifications have to be made before those data can be used. First, a link in the Handbook is defined in terms of where traffic flow varies by 10 percent [Nagle, 1994]. This means that there are far more links listed in the Handbook than in the Indiana network database in its current form. For modeling purposes, a link is defined by the two end nodes. If the end nodes have only one other connector, the link and the nodes may not be necessary and can be removed from the network while still retaining the network characteristics. In other words, a node must have more than two connectors to be considered essential. Three scenarios shown in Figure 6.1 will clarify the definition of a link in the network model versus in INDOT's Handbook. In this figure, Scenario X would not be consistent with standard network structure, although it may be represented this way in the traffic handbook. Node B can be eliminated because it has only two connectors. Links A-B and B-C can be represented by one link; Scenario Y is the preferred form. Node G in Scenario Z is necessary, because it has three nodes connected to it. In order to include all the links in INDOT's Handbook, so many more links and nodes would have to be added, that TranPlan's capacity may be exceeded.

Aggregation of INDOT's traffic data is necessary to conform with the TransCAD network data. (See Section 1.5.) A problem arises when traffic values are to be assigned to the TransCAD network links, where each link may represent two or more segments in INDOT's Handbook. Instead of taking an average of the count on segments in the Handbook or some mathematical procedure in joining segments, those segments that crossed county lines are given the highest priority in assigning a link count. The Fast Matrix Calibrator (FMC) is concerned with matching screenline counts and the study is interested in interzonal traffic flow; the above aggregation would satisfy the conditions set by the software.

An example is illustrated in Figure 6.2. Link B-C-D is represented by six segments in the INDOT Handbook. Because the link lies across the county line, the traffic count that corresponded to the segment, 6220, is assigned to Link B-C-D. When links do not lie on county lines, the links are assigned a traffic count as follows: 1) If the link represents three or more segments, a median traffic volume of the set is used. This means neither the highest nor the lowest traffic volumes are ever used in coding the network. In Figure 6.2, Link A-B represents 4 segments, whose traffic counts are: 13950, 9250, 7820, and 5810. Either 9250 or 7820 can be used but 9250 better represents the four segments because the value is closer to the average of the four segments. 2) If there are two segments that are represented by a link, either one could be used. The higher priority is given to the traffic volume that has a value closer to that on nearby links that have already been accepted for this analysis. Link E-B of the same figure is an example of the second condition. Two segments, with traffic counts of 390 and 610, are recorded in the Handbook. The higher value is chosen for the network data in TransCAD because it is closer to the traffic volumes on the surrounding links.

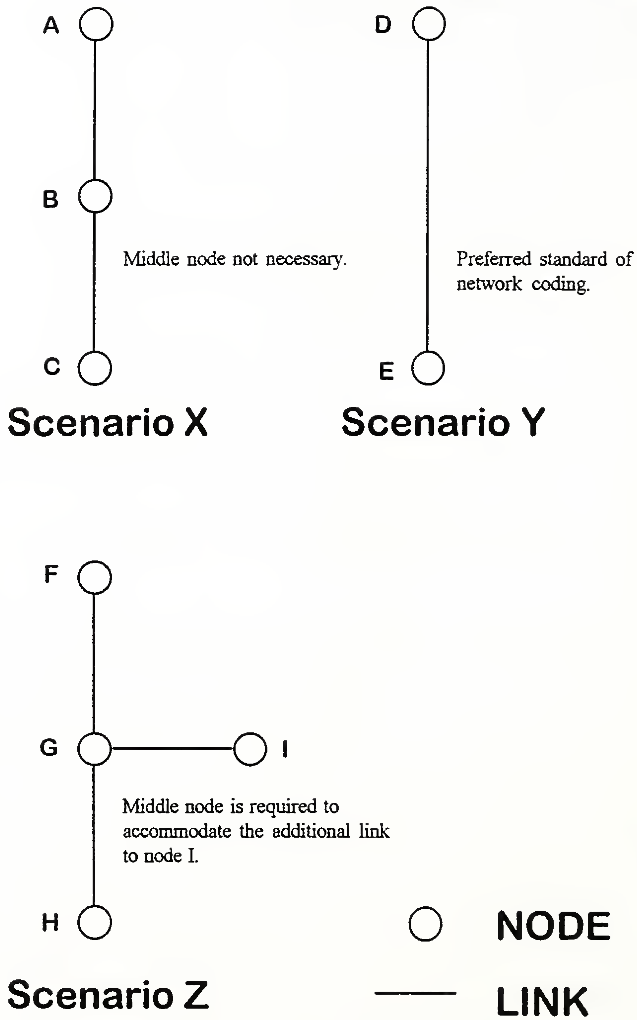

Figure 6.1 Link Diagram

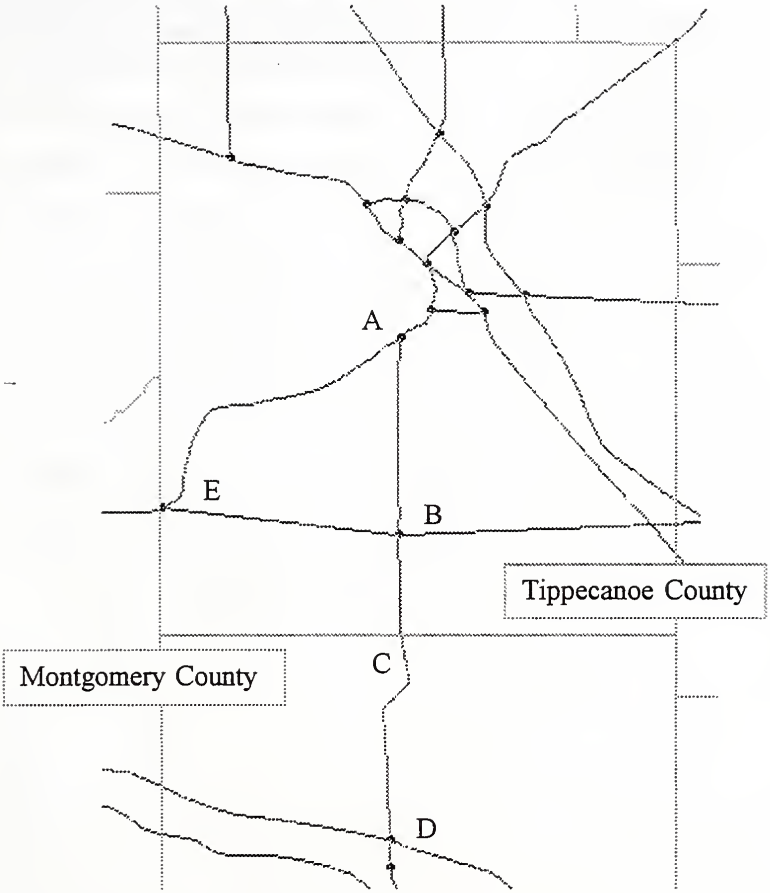

Figure 6.2 Traffic Data Assignment on a Partial Indiana Network

6.1.1 Capacity Issue

Hourly highway capacity has been established for some time now, depending on its lane width, lateral obstruction, traffic composition, grade, and speed [Garber and Hoel, 1988]. However, 24-hour capacity has not been standardized. It would not be accurate to simply multiply the hourly capacity by 24; this would overestimate the capacity. For the Indiana network, 24 hour capacity values were obtained from a Florida DOT planning manual [FDOT, 1988]. From this manual, 23 capacity classes were extracted, based on the location, highway class, and number of lanes on a particular link. For Indiana, there are 12 metropolitan areas and the links within those areas were given the "URBAN" code, while rest of the links received the "RURAL" code. For the highway class, those links that were interstate freeways got the "FREEWAY" code; otherwise, links received the "ARTERIAL" code. The third distinction was the number of lanes-- the more lanes a link has, the more capacity it will receive. The highest number of lanes in the FDOT manual was ten, which is sufficient for the Indiana network. Figure 6.3 shows the flow chart that illustrates how a capacity was assigned to the TransCAD database. For example, if a link has 4 lanes, a speed limit of 45 mph, and is not within the 12 MPOs, it will receive a 24-hour capacity of 25100 if no highway median exists. However, if there is a median separating the two directions, the link capacity increases to 26400.

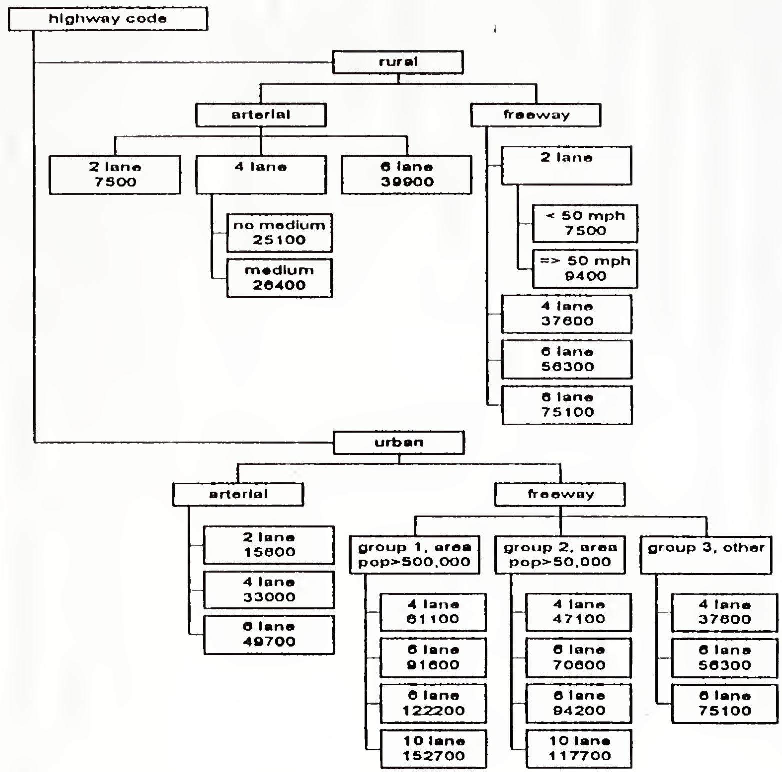

Figure 6.3 24-Hour Capacity Assignment Flow Chart

6.1.2 Zonal Trips

In the calculation of origin-destination tables, FMC requires as input the number of trips that are attracted and produced in each zone. Traditionally, there are two classes of trip generation models: linear regression models and cross classification models [Federal Highway Administration, 1975]. Variables used as predictors of trip productions include household income, auto ownership and size, number of workers per household, residential density, and distance of the zone from the central business district (CBD). Trip attraction predictors include zonal employment levels, zonal floor space, and accessibility to the work force [Meyer and Miller, 1984]. Some of these variables may not apply to this study, because the models mentioned above are for a small area and this study deals with a statewide network. Both methods require socioeconomic data that this study lacks and it is impractical to obtain those data. The O-D study is concerned with intercounty flows, so that the trips that cross county lines could be used to estimate the attraction and production values. A 50/50 split is assumed for the attraction and production values; the sum of the trips that went across county lines is split in half. TransCAD has the ability to save the selected links in a "SET" file, so that they could be retrieved for later use. Each county has its own file, which makes revisions and double checking easier to perform. In addition, TransCAD has a feature to tally the trips on those "SET" files. These values from the "SET" files becomes the estimate for zonal production and attraction values.

6.1.3 Data Conversion

The Indiana network data are stored in TransCAD, which is a transportation-oriented geographic information system (GIS). TransCAD offers features in data manipulation and query that are not present in TranPlan. Although conversion procedures are required to make the database compatible with TranPlan, the extra work is well worth the advantages that are gained by using TransCAD to store and manipulate data. Some of the advantages include the ease of importing and exporting data, either in ASCII, dBASE III, or comma-delimited format. Other features include a screen editor where the network can be displayed and modified, a layer feature to store various types of data, and arithmetic computational ability [Caliper, 1992]. In the next section, the conversion process will be fully discussed and explained.

6.2 TransCAD Data Structure

The Indiana network consists of six layers of data, named Intersection, Highway, County, State, Place, and Zone Centroid. The Intersection layer is also called the Node layer. This layer has the coordinate information on where each node is positioned. The Highway layer is also known as the Link layer in modeling terms. This layer contains the information necessary to build a network model, such as link distance, speed, traffic count, and link connectivity information. The County layer contains the boundary data, tracing out the shape of each county. This contains what are commonly referred to as the shape points. The State layer is similar to the County layer, but with the addition of some socioeconomic data. The socioeconomic data are for use with IU's commodity flow project and have little value to this study. The Place layer has city locations and socioeconomic data. Finally, the Zone Centroid layer contains the centroid locations. This assumes that there is one centroid per zone. If zones are further subdivided or rezoned, this layer would need to be revised to accommodate the additions.

6.2.1 TransCAD to TranPlan Data Conversion

Four files are used to convert the Indiana network database into TranPlan format. Three of them are exported from TransCAD and the other one is obtained indirectly from TransCAD. The four files consist of node, link, centroid, and zone connector files necessary to create the networks in TranPlan. As each file is described below, note that the name in parentheses is the exact name that must be supplied with the export of comma-delimited files in TransCAD, so that the conversion programs are able to locate these files. The node file (NODEFILE.TXT) contains positioning information of nodes in the database. The link file (LINKFILE.TXT) contains the information needed to construct the network: information such as link distance, speed, traffic count, capacity, and most important, Anode and Bnode information. The measurements are in longitudes/latitudes, while TranPlan accepts units in state plane coordinates. Because the link distances are already known, precise positions of the nodes are not necessary. Therefore, the longitude/latitude data are not converted into state plane coordinates, but into a record length that TranPlan will accept. The centroid file (CENTROID.TXT), has one node per zone. In the case of the Indiana network, there are 92 nodes corresponding to the number of counties. The zone connector file (CENTCONT.TXT) contains the centroid connector information and the traffic generated by each zone. This file is constructed with the information coded in TransCAD; an editor is needed to create this file. The information in the third field is the result of utilizing TransCAD's tally feature discussed in the Section 6.1.2.

Tables 6.1-6.4 are samples of the exact fields that are exported. To the properly export the data fields, following the exact format will contribute to a successful data conversion to TranPlan format. The file names should be named "NODEFILE.TXT", "LINKFILE.TXT", "CENTROID.TXT", and "CENTCON.TXT", respectively. Headers for the first three files need to be removed before the conversation program is executed. Otherwise, the program will not run correctly.

Table 6.1 Node Layer File Format

ID	Longitude	Latitude
200	-84678206	41793265
201	-84556350	41822961
202	-84513342	41226993
203	-84339262	41272049
204	-84603454	40803057

Table 6.2 Link Layer File Format

ID	Meas. Length	A-node	B-node	Speed	AADT	Capacity
1700073	1.60	1700033	500	65	18470	37600
1700325	7.60	498	1700027	50	1320	7500
1800001	0.85	511	5600376	40	21500	33000
1800003	3.00	1800189	1800378	40	30610	33000
1800004	6.70	1800378	1800379	55	19280	33000
1800005	8.80	1800378	1800355	45	6440	15600
1800007	3.60	1800382	1800482	45	44720	33000

Table 6.3 Centroid File Format

ID	Longitude	Latitude
1	-84939200	40742200
2	-85015000	41067500
3	-85896900	39215600
4	-87315500	40618300
5	-85371000	40450100

Table 6.4 Zone Connector File Format

zone	connected node	total traffic volume (2-way)
1	3029	25280
2	7357	136050
3	3151	106060
4	7369	13280
5	3069	5320

6.2.2 Conversion Programs

A two-part program was written for the conversion of the database stored in TransCAD. The program was coded in MS-FORTRAN. Due to the error message "Insufficient Memory", which could not be resolved with the original program, the program had to be broken into two parts: the first part converts the node data while the second part converts the link data. The two-part programs need to be executed successively, making sure each time the second part of the program is run only once. Converted files may contain more information if the second part of the program is executed without running the first program because the "APPEND" file feature is utilized, as will be discussed.

Two conversion programs were designed to handle up to 2000 links and 1000 nodes. Program 1 converts the node data, while Program 2 converts the link data. The algorithm was as follows: A final output file (NET.DAT) is created after the programs have been executed. This is the file that TranPlan uses to construct the network. The internal centroid file (CENTROID.TXT) and the node data files (NODE.TXT) are read next; their formats were discussed in the previous section. In the next step, external zones are selected and new node numbers are given. Because the external zones are not identified in the TransCAD database, a subroutine was added to identify those external centroids. The next step involves node numbering conversion. This is because TranPlan accepts node numbers up to five digits long, while the information given in TransCAD has seven digits. Various conversion specifications have been devised, with the current form satisfying the condition that every converted node has a unique number and the largest number does not exceed 10,000, as set by TranPlan. The TranPlan user manual suggested a limit of 16,000 nodes, but experience has shown this is not so. The converted TranPlan node number can be easily converted back into its TransCAD node number. This is discussed in the next section. The next step involves coordinate conversion. TranPlan uses state plane coordinates, while TransCAD uses the longitude/latitude convention. Although the conversion does not convert the coordinates into state plane coordinates, it does convert the coordinates to meet TranPlan's field length requirement. The loss of accurate position information would not be crucial to the calculation of link distances, because the network database already provides this information. The converted information is written onto the file (NET.DAT) that would later be used in TranPlan procedures to build the statewide network.

The second program is similar to the first one, except it converts the node numbers in the TransCAD link list to TranPlan node numbers. This time the newly converted information is appended to the output file (NET.DAT) already created by the first program. The node and link conversion codes are separate programs that have to be run one time each in the proper sequence. For the link conversion program, the centroid connector file (CENTCON.TXT) is read in first. The last field is the traffic generated in each zone. This is one of many critical data fields, because it determines the amount of traffic to be loaded onto the network. The next step involves reading the link file (LINKFILE.TXT). This file contains all the information needed to construct the network. The next steps are similar to Program 1, sorting out the external nodes and converting node numbers into five-digit lengths. Lastly, the information is written to the file "NET.DAT". The programs are named CONV1.EXE and CONV2.EXE.

6.2.3 Node Number Convention

The node numbers in the Indiana network were converted according to the following conventions: Node numbers from 1 to 299 were reserved for internal and external centroids. All nodes with a number in TransCAD greater than 1,000,000 were converted. The node numbers that were converted fall into the six levels given in Table 6.5. The table shows the conversion scheme for the nodes, by which all nodes were converted and given a unique number. For example, node 1,800,078 became node 3078. This scheme will become clear to users as they become familiar with the TransCAD node numbering system. The conversions in Table 6.5 apply only to the Indiana database, however.

Table 6.5 Node Number Conversion

TransCAD Database	Converted Value
1,700,000+	1500+
1,800,000+	3000+
2,100,000+	4000+
2,600,000+	5000+
3,900,000+	6000+
5,600,000+	7000+

6.2.4 TranPlan Batch File

In order to build a network in TranPlan, a batch file is required to identify input and output files, along with control variables. The batch file used to construct the Indiana network is seen in Table 6.6. The lines that start with "$" are standard TranPlan control lines. Under "$OPTIONS", "NETDATA" specifies that all data transactions for this function are contained in the file "NETDATA" which, in this case, must be present as an input file, and "LARGE COORDINATE" specifies that coordinate data are in the form of one node per record. This option complies with the state planar coordinate systems [UAG, 1992].

Table 6.6 TranPlan Network Building Batch File

```
$BUILD HIGHWAY NETWORK
$FILE
   INPUT FILE = NETDATA, USER ID = $NET.DAT$
   OUTPUT FILE = HWYNET, USER ID = $HWYNET.XXX$
$HEADERS
      INDIANA NETWORK
      PURDUE UNIVERSITY
$OPTIONS
   NETDATA
   LARGE COORDINATES
$PARAMETERS
   NUMBER OF ZONES = 115
   MAXIMUM NODE = 10000
   ERROR LIMIT = 50
$END TP FUNCTION
```

6.2.5 Statewide Network

The final Indiana network consists of 737 nodes and 1156 links. (See Figure 6.3.) All the links in the network are two-way, with 2-way traffic counts divided 50/50 for each direction. 92 internal zones and 23 gateways are parts of the statewide network. Some external gateways are combined to reduce the number of screenlines to be used with FMC. This will be discussed in Chapter 7.

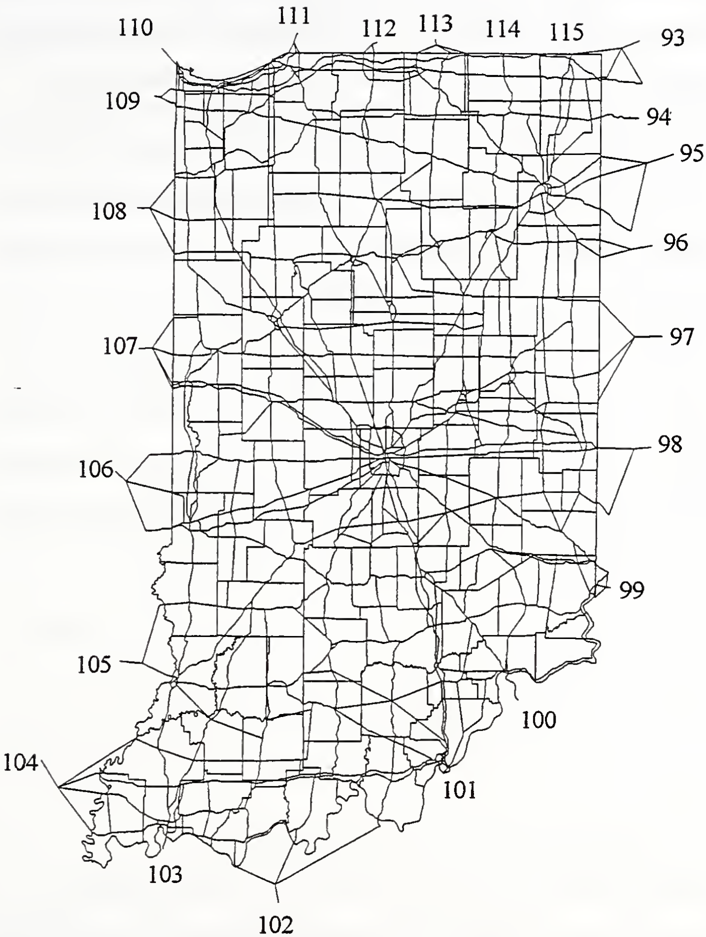

Figure 6.4 Indiana Network with County Boundaries

6.3 Conclusion

The maintenance of the network database is a continuous process that must be suspended in order to proceed with building the network and other procedures. The data used in network construction are from 1991 data with 1992 updates [INDOT, 1991]. Essentially, the network information is the same as with the *1992 Highway Statistics Handbook*, which was the most recent edition when the network database was constructed. A few assumptions were made when constructing the network and the database. The assumptions involved the directional split of the traffic counts and estimation of production and attraction values. As more data become available, they can be incorporated into the network. The conversion programs can be executed with the updated database and TranPlan network can be build in short amount of time. The conversion programs worked very well in preparing the files for constructing the Indiana network in TranPlan. The programs are flexible enough to work with other data sets, provided the node numbering scheme follows the existing format. TransCAD provided an appropriate environment for the network database. GIS is a important tool for building network and managing data. With the conversion programs, TranPlan/FMC is able to benefit from TransCAD's features while retaining its own strong points.

CHAPTER 7 FMC APPLICATION

This chapter will discuss the steps taken before the FMC batch file is executed to obtain synthesized O-D tables. Each step will be discussed in enough detail to give the reader all the information required for a successful computation. Additional information can be found in Chapter 4. This includes the discussion of various FORTRAN programs specially developed for the task of preparing and constructing input files for FMC. All the files are stored on a 3.5 inch diskette for delivery to users at INDOT. File extension names ".FOR" and ".EXE" are for FORTRAN source code and compiled programs, respectively. Files with the extension ".IN" are TranPlan batch files. These extensions are mandatory, so that TranPlan recognizes the file and performs the proper operations. The following sections will discuss the three input files for FMC. The first file contains the initial trip table information. The second file is the ASSEVA file, which contains the list of links that are used for matching traffic volumes in the O-D matrix calculation. The third required file is the selected link history file, which contains the loading history of the links to be used in the ASSEVA file. Section 4 of this chapter will discuss the batch file and output of FMC. The final section will describe the spreadsheet written to reformat FMC output data into more usable and readable format.

7.1 Preparing Initial Trip Table (APRIOR File)

An initial trip table or seed table is required as one of three input files. This table contains prior O-D information regarding the network. In general, this can be a trip table from a previous study that is considered suitable for updating. In this study, because no prior O-D information for the Indiana state network is available, other initial trip tables are used instead. These alternate initial trip tables include level, OD Factored, and modified level trip tables. The first two types of initial matrices have been discussed in Chapter 1. The last type, modified trip table, is a level matrix with two values. A value is given to the cells that are internal-internal, external-internal, and internal-external trips; a second value is given to the external-external trips, often a higher value to represent heavy through traffic. Any ASCII editor can handle the task of constructing the input file, but with patience and skill. The large network in this study had a trip table that is 115 zones by 115 zones. This size matrix translates to 13225 lines (cells) of input data, because the TranPlan batch file requires that the data for each O-D pair (origin zone, destination zone, trip purpose, number of trips) be stored on a separate line. The burden of this data entry task is compounded if other initial trip tables are needed, such as a variety of matrix cell values for testing purposes. A program has been written to simplify the task of generating input data for both types of level trip tables. The program (SEEDTAB.EXE) is used to generate the data for TranPlan on both types of level trip tables. The computer program prompts the user for the number of zones and cell values which are to be entered from the keyboard. The output file (LEVEL.TXT) is then used as the input for TranPlan's Trip Table Building Module file (TTABLE.IN) shown in Table 7.1. This module builds a trip table that is used internally among TranPlan procedures. The output file (VOLUME.XXX) will contain the level trip information that will be used in other TranPlan procedures.

Table 7.1 Trip Table Building Batch File

```
$BUILD TRIP TABLE
$FILES
      INPUT FILE = SRVDATA, USER ID = $LEVEL.TXT$
      OUTPUT FILE = VOLUME, USER ID = $VOLUME.XXX$
$HEADERS

$OPTION
      PRINT TRIP ENDS
      SIMPLE
$PARAMETERS
      NUMBER OF ZONES = 115
      NUMBER OF PURPOSES = 1
$DATA
      TABLE 1 = ALL
$END TP FUNCTION
```

7.2 Constructing Link File (ASSEVA File)

ASSEVA, short for assignment evaluation, is the file that contains information on screenlines regarding count locations and count values that are to be used to synthesize O-D tables. This link information file (EXTWIM.SET) is stored in TransCAD and needs to be exported into ASCII format. The file can be modified on screen to accommodate difference loading scenarios, which is another benefit of using GIS software to store and manipulate data. A FORTRAN program (ASSEVA.EXE) is used to convert the exported file (EXTWIM.TXT) from TransCAD into a format that FMC can read. FMC uses a strict file format and the ASSEVA.EXE program's output file conforms to these requirements. The FMC input file must contain only one-way links, so the program takes the two-way links from TransCAD and splits them into two one-way links. Because FMC can handle up to 450 one-way links, care should be taken when defining the screenlines to be used with O-D calculation. The ASSEVA file includes centroid connectors, weigh-in-motion (WIM) stations, and classification locations. The rest of the links in the file are high-volume links, because they are more important in matching link counts than low-volume and less-traveled links. Each screenline can include up to five links. These links must be registered in the SELHIST file, which will be discussed in the next section. The order of the numbers does not matter, as long as they are between 1 and 450. The format for the file is seen in Table 7.2 [UAG, 1993].

Table 7.2 ASSEVA File Format

Column(s)	Type	Description
1-5	I5	ANODE, junction of origin
6-10	I5	BNODE, junction of destination
11-14	A4*	Counting point
15	A1*	Direction
16-20	I5	Screen line number
21-28	I8	Counting value from ANODE to BNODE
34-59	S26*	Information

* These fields are not used by FMC. They provide additional information for the user.

7.3 Preparing Select Link History File

SELHIST.XXX is the final input file for FMC. This file contains all the links that are found in the ASSEVA file. This is essential because this procedure records the loading conditions of the network. This file may contain more links than the ones found in the ASSEVA file. The TranPlan user manual indicated that the procedure is the bottleneck of the 450 link limit. This procedure will not allow more than 450 links to be loaded. It is hoped that this limitation can be eliminated by the developers of TranPlan in the future.

A SELHIST batch file (Selected History) contains the links that will be used as screen lines. It records if an O-D relationship used one or more selected links [UAG, 1993]. Before the batch file is invoked, the section under "TWO WAY SELECTED LINKS" needs to be filled. This section contains the links that are to be loaded onto the network. The information is entered in a two-way format instead of one-way because all the links are coded two-way under TransCAD. A program (SELHIST.EXE) is written to construct this information. The program uses the same input file as the ASSEVA file does to construct this critical section. The output from this program (SELHIST.TXT) contains the link identification information defined by their end nodes. The section can be constructed by using an ASCII editor, but such repetitious work can be eliminated when the program (SELHIST.EXE) is applied. This output file (SELHIST.TXT) is inserted into the batch file under the entry "TWO WAY SELECTED LINKS" shown in Table 7.3.

Table 7.3 SELINK Loading Batch File

```
$LOAD HIGHWAY SELECTED LINKS
$FILES
      INPUT FILE = HWYNET, USER ID = $HWYNET.XXX$
      INPUT FILE = HWYTRIP, USER ID = $VOLUME.XXX$
      OUTPUT FILE = LODHIST, USER ID = $LODHIST.XXX$
      OUTPUT FILE = SELHIST, USER ID = $SELHIST.XXX$
$HEADERS
      RESEARCH PROJECT
      PURDUE UNIVERSITY
$OPTIONS
      CAPACITY 2
      DAMPING
      PRELOAD LINKS
$PARAMETERS
      IMPEDANCE = TIME 1
      SELECTED PURPOSE = 1
    - TWO WAY SELECTED LINKS =
1-3059,
2-5289,
...
$END TP FUNCTION
```

7.4 FMC Batch File

Before the FMC batch file is constructed and executed, the optional flag matrix file should be mentioned. This file has the same dimensions as the trip table, and its cells contain only "1" or "0" values. The cell value tells FMC whether a cell value can be changed. A value of "1" indicates that no change can be made; otherwise, "0" means that changes according to FMC can be undertaken. It is recommended that the Flag Matrix only be used in exceptional circumstances and very cautiously. There can be imbalances between the relationships that are changed on the basis of the screenline(s) and those that have a relation with the same screen line and may not be changed [UAG, 1993]. This optional file is not used for the Indiana network because no prior knowledge regarding traffic flow pattern is known, i.e., O-D pairs. As more information is gathered about flow patterns, this optional file can be beneficial in synthesizing O-D matrices.

The last file constructed is the job control file (FMC.IN). This is shown in Table 7. 4. This file has the control parameters discussed in Chapter 4. In the data section of the control file, additional zonal and/or screen line elasticity values can be assigned in addition to the default values. The format for the data section is shown in Table 7.5.

Table 7.4 FMC Batch File

```
$FAST MATRIX CALIBRATION
$FILES
      INPUT FILE = APRIOR, USER ID = $VOLUME.XXX$
      INPUT FILE = ASSEVA, USER ID = $ASSEVA.TXT$
      INPUT FILE = SELHIST, USER ID = $SELHIST.XXX$
      OUTPUT FILE = FMCMAT, USER ID = $FMCMAT.OUT$
$HEADERS
      INDIANA NETWORK
      PURDUE UNIVERSITY
$OPTIONS
      NO AUTO GROWTH FACTOR
      NO BUCKET ROUNDING
$PARAMETERS
      NUMBER OF ITERATIONS = 100
      SCREENLINE CLOSURE = 1.0
      MINIMUM CHANGE = 0.1
      COEFFICIENT CLOSURE = 0.001
      DEFAULT ZONAL ELASTICITY = 0.00
      DEFAULT SCREENLINE ELASTICITY = 1.0
      GROWTH FACTOR = 1
GROWTH FACTOR = 1
$DATA
S   1   1.0
S 226   1.0
S   4    .8
S 229    .8
$END TP FUNCTION
```

Table 7.5 FMC Data Section Format

Column(s)	Type	Description
1	A1	"S" or "Z" designates screenline or zonal elasticity
2	-	Not in use
3-5	I3	Screenline or zone number
6	-	Not in use
7-11	F5.3	Elasticity

In the "OPTIONS" section, a few preferences are seen. With the "No Auto Growth Factor" option, the ability to determine the growth factor with respect to the initial trip table is disabled. This feature is not relevant to the study, because a new O-D table is created without reference to an outdated matrix. The comparison also makes no sense when the growth factor is irrelevant when compared to a level trip table. As for screenline and zonal elasticities, "1" means the information is very reliable and "0" expresses extreme uncertainty about the data and the reason for re-calibration of the value of that particular cell or link. Although all the cells will be updated, regardless of the elasticity settings, the elasticity value indicates the degree to which changes will take place with respect to other cells. Refer to Chapter 4 for more information on the elasticity values.

Two files are produced as the result of running FMC: a status file and an O-D file. The status file contains the following information: Control information (batch file), intermediate calculations, changes compared to the initial trip table, and error messages, if there are any. The O-D matrix file is in binary code as produced by FMC. An ASCII version can be obtained using the "TPCARD" command, which is one of many utility programs included in TranPlan.

Of interest when performing FMC is the process time, because a user may consider applying FMC to a real-time situation application, e.g., advanced traffic information systems. In Figure 7.1, the process times of an FMC run of 50 iterations under DOS and Windows environments are presented. The process time is directly related to the number of iterations, with each iteration taking approximately the same time. Contrary to intuition, FMC runs faster under the Windows environment than in DOS. This may be due to the setting up of the PIF file for the DOS environment in Windows. The DOS environment is assigned the maximum available computer memory. The computer used for processing was a Gateway 486DX-2 computer with 24 MB of RAM. Additional memory may be the basis for the decreased process time, considering that the PIF file is allocated more memory in Windows than in the traditional DOS environment. DOS 6.2

lacks the capability to access the additional memory installed in the computer. A RAM Drive is not recommended in this case, because most of the calculations are done internally within the CPU and the transferring of files to the hard drive is minimal. Therefore, creating a RAM drive will not reduce processing time significantly, but takes away from what memory the computer has.

The minimum hardware configuration for FMC and related programs will be a 486DX computer with at least 8 MB of RAM. As discussed in the next section, an Excel program is written for the study that will require additional memory under the Windows environment. To further increase the efficiency of the computer, create the largest swap size possible under Windows. A permanent swap file is faster than a temporary swap file [Microsoft, 1992].

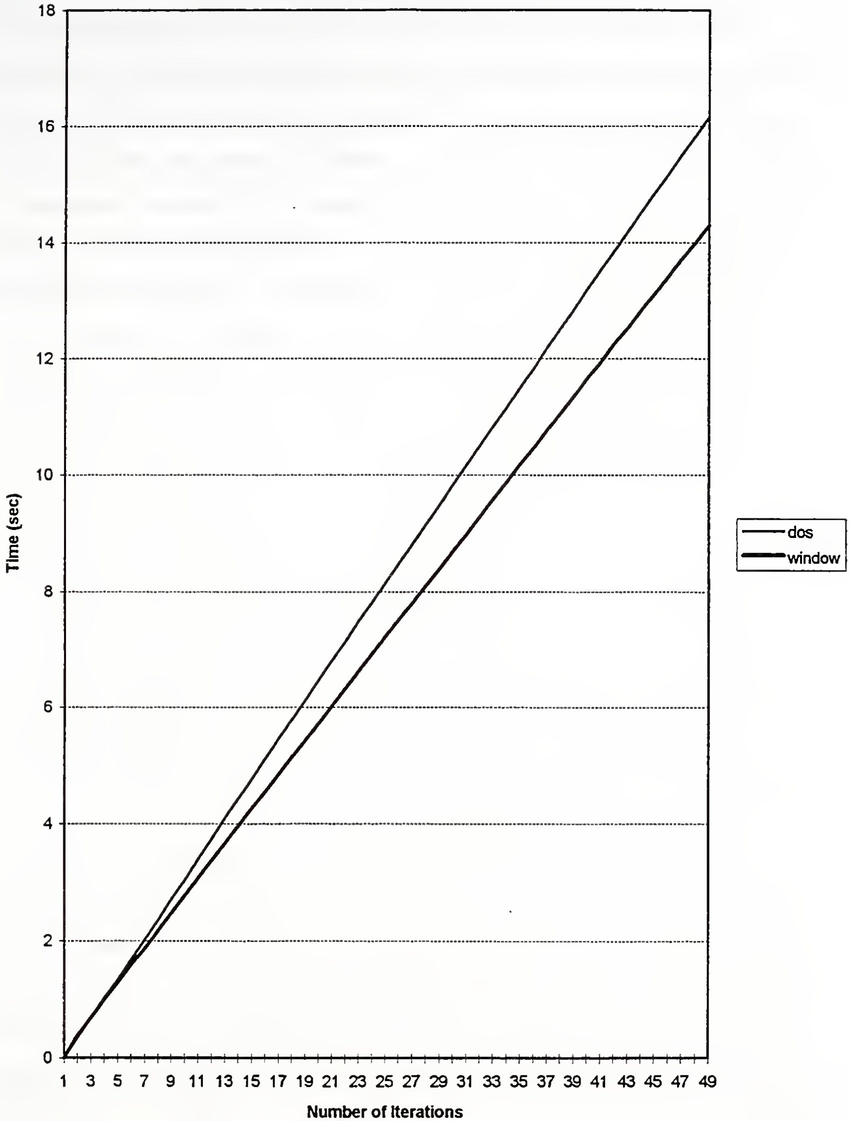

Figure 7.1 Time vs. Number of Iterations

7.5 Output Reformat

Shown in Table 7.6 is a partial ASCII version of the calculated trip table. As seen from the O-D table, the output file is in a format such that each of the 115 origin zones contains eight columns and 15 rows. This means that there are 115 eight by 15 chunks of data present in the output file. An editor is needed to rearrange the data into a more readable form, such as a true matrix format (115 by 115). However, this is time consuming; with every new output, the process of rearranging data has to be performed.

The idea of repeatedly moving data around with an editor led to the idea of using a spreadsheet program to carry out the task. In this study, Microsoft's Excel 5.0 spreadsheet was chosen for various reasons. Ease of writing macros was one of Excel's most desirable features. In addition, the layer feature in Excel proved especially helpful in this study. Multiple sheets can be embedded into one file, with number of layers limited solely by the computer's memory [Microsoft, 1993]. For the Indiana network, each layer will contain an origin zone, creating 115 layers. Two additional layers are needed, one for input of raw (unformatted) data and another for the output of the final O-D table. An example of the raw data is shown on Table 7.6, it contains two origin zones with respected destinations zones. Two other layers are added as the result of macros. As a result, the spreadsheet contains 119 layers and occupies over 1.8 MG of disk space. A compressed version of this file (FMC_TEMP.XLS) is available, because the uncompressed file would not fit on a 3.5 inch high-density disk.

The methodology behind the layered structured is that every layer (origin zone) will read the corresponding trip cells from the "DATA" layer. This is done for all 115 zones. In each layer, the trips are reformatted from 8x15 into a one-dimensional format. The final matrix layer will read the single-dimension array from the 115 layers and organize it in a way that represents a true 2-dimensional matrix. This layer also has the total origin and destination sums displayed, as well as the total number of trips in the matrix.

To use the spreadsheet, first open the ASCII version of the trip table in Excel with the "space delimited" option. Next, copy the entire ASCII file starting from zone 1, and paste it into the “DATA” layer of the spreadsheet. After some time, depending on the speed of the CPU, the O-D output for a single matrix format can be seen in the layer “OD MATRIX”. The layer can be printed in a number of configurations: either all on one page (very small print) or on multiple sheets. Experience has shown that an 8-sheet configuration is a good compromise between print size and number of sheets. A typical sample output (condensed) can be seen in Table 7.7. This output has some of the rows and columns deleted in the interest of space, but it shows the features included in the spreadsheet. Zone numbers are shown on all sides. The right and bottom sides of the worksheet have the total production and attraction values, respectively. Gray bars come after 40th and 80th zone to help the readability of the worksheet when it is separated into multi-sheets.

Table 7.6 Partial ASCII Version of the Final Trip Table by FMC

1	1						
0	110	535	5	48	51	0	5
5	0	0	32	0	0	186	257
49	1900	0	35	225	0	12	32
8	0	52	0	213	263	0	0
1385	70	1299	0	40	277	22	87
0	0	3	44	0	1	0	15
908	8	0	18	0	11	0	26
20	12	0	0	7	0	0	14
0	0	0	449	23	26	357	0
107	0	3	59	0	2	75	12
156	0	14	0	334	8	0	0
1320	199	40	37	27	4	11	165
117	655	121	7	0	0	0	0
0	0	6	5	0	0	0	0
2	12	0					
2	1						
110	0	0	14	69	131	0	15
16	0	0	85	0	0	79	7
8871	65	0	6018	47	0	32	9
1326	0	129	0	504	23	0	0
53	165	1796	0	9479	58	10	0
0	0	205	5190	1	35	0	47
126	493	0	50	0	30	0	65
3504	5	0	0	19	0	0	501
0	12	0	91	10	1	3452	0
10	0	130	10568	0	1	186	35
32	0	38	0	483	23	0	0
268	1194	105	3516	4822	694	1897	33
24	135	52	3	0	0	0	0
0	0	19	12	0	0	0	0
12	788	0					

FROM\TO	1	2	3	38	39	40	41	42	43	78	79	80	81	82	83	113	114	115	TO/FROM	TOTAL
1	0	1250	497	198	17	60	0	0	4	1	83	16	91	0	13	3	26	0	1	13784
2	105	0	0	56	8	0	0	0	238	1	171	51	30	0	45	143	1274	0	2	68087
3	497	0	0	0	508	546	1563	2676	13	22	0	212	399	0	50	1	0	804	3	53068
4	3	17	0	8	0	0	0	0	70	0	491	19	0	2	1	0	0	0	4	6628
5	25	104	0	10	8	8	0	0	15	0	117	16	4	0	12	1	2	0	5	2655
6	66	140	0	352	0	0	0	14	625	0	274	0	0	27	503	1	0	7	6	48990
7	0	0	321	0	6	26	765	181	4	0	0	81	15	90	111	0	0	32	7	9114
34	73	171	55	88	8	15	166	51	127	2	3741	9	47	75	637	0	0	33	34	28740
35	1314	1779	0	638	0	0	0	0	184	0	89	42	5	0	17	281	343	0	35	32807
36	0	0	557	0	443	473	340	168	6	18	0	78	60	1390	893	0	0	53	36	39555
37	41	9501	0	33	0	0	1	3	897	0	438	54	0	8	12	0	0	1	37	35563
38	198	56	0	0	8	67	0	0	2	0	102	113	39	0	177	1	15	0	38	9866
39	17	8	508	8	0	48	77	24	2	1	0	24	4	0	6	0	0	6	39	13644
40	60	0	546	87	48	0	312	25	4	1	0	54	30	0	12	0	0	6	40	12431
41	0	0	1563	0	77	312	0	1	36	7	0	816	973	0	183	1	0	0	41	76322
42	0	0	2676	0	24	25	1	0	14	1	72	110	0	1542	12	0	0	373	42	18222
43	4	238	13	2	2	4	36	14	0	0	825	1	1	37	117	47	4	3	43	18546
44	36	4718	0	18	0	0	0	0	744	0	1	20	10	0	0	18	347	0	44	28627
45	1	8	1	35	0	0	1	3	2	0	236	49	0	5	7	24	7	1	45	146748
46	5	113	0	3	0	0	0	0	64	0	35	1	2	0	0	0	0	0	46	103466
47	0	0	280	0	169	176	94	70	52	5	25	411	19	122	128	5	0	18	47	15019
74	0	0	0	0	0	0	0	57	0	0	1136	0	0	11348	2	0	0	19	74	25220
75	3	116	0	2	0	0	0	0	52	0	1169	1	1	0	0	0	0	0	75	20377
76	50	10575	0	26	0	0	0	0	45	0	120	26	14	0	0	25	511	0	76	36012
77	0	0	1967	0	192	200	1	1085	10	6	53	99	0	1198	9	0	0	252	77	15202
78	1	1	22	0	1	1	7	1	0	0	0	5	0	0	1	0	1	0	78	1171
79	83	171	0	102	0	0	0	72	825	0	0	155	0	113	665	1	0	22	79	49501
80	16	51	212	113	24	54	816	110	1	5	155	0	54	158	0	0	0	70	80	22612
81	91	30	399	39	4	30	973	0	1	0	0	54	0	0	0	1	10	0	81	6852
82	0	0	0	0	0	0	0	1542	37	0	113	158	0	0	32	0	0	585	82	72124
83	13	45	50	177	6	12	183	12	117	1	665	0	0	32	0	0	0	3	83	20274
84	0	0	0	0	0	0	0	173	2295	0	9598	172	0	234	1855	0	0	55	84	47506
85	256	565	3	115	1	1	8	8	148	0	25	0	9	14	4	46	55	5	85	12825
86	7	28	72	46	7	15	294	7	60	1	380	59	0	21	49	0	0	1	86	12642
87	0	0	0	0	0	0	0	542	0	0	45	0	0	32485	11	0	0	185	87	45931
109	0	7	0	0	0	0	0	2	0	0	9	2	0	4	5	1	0	1	109	70395
110	3	4	0	2	0	0	0	0	19	0	3	1	0	0	0	0	0	0	110	24137
111	0	0	0	0	0	0	1	1	1	0	38	0	0	2	2	0	0	1	111	21559
112	0	20	1	0	0	0	2	0	0	0	1	0	0	0	0	1	0	0	112	17564
113	3	143	1	1	0	0	1	0	47	0	1	0	1	0	0	0	1	0	113	4569
114	26	1274	0	15	0	0	0	0	4	1	0	0	10	0	0	1	0	0	114	4320
115	0	0	804	0	6	6	0	373	3	0	22	70	0	585	3	0	0	0	115	5636
FROM/TO	1	2	3	38	39	40	41	42	43	78	79	80	81	82	83	113	114	115	TO/FROM	
TOTAL	12622	69369	53067	9274	13644	12431	76320	18221	17900	1171	48605	22064	6556	72123	18804	4566	4317	5636		3353642

Table 7.7 Sample Reformatted O-D Output

7.6 Conclusion

Extreme care should be taken when constructing and preparing files for FMC. The slightest mistake, be it typographical or otherwise can halt the process of calculating O-D tables. The FORTRAN programs (SEEDTAB.EXE, ASSEVA.EXE, SELHIST.EXE) discussed in this chapter (Sections 7.1, 7.2, 7.3) are valuable in saving time and minimizing frustration while preparing input files. Although the programs are designed specially for the Indiana database in TransCAD, the programs can be easily modified to accommodate other sets of data and format since the source code is also included with the project. The programs are designed for internal use and written with comments that annotate the steps. The operating time depends directly on the number of iterations requested and the speed of the computer. With the aid of Excel, output can be easily displayed in a normal and easy to understand fashion. A 486DX computer with no less than 8 MB of RAM is recommended, because of the size of the spreadsheet and the software capacity. The results of the statewide O-D calculations are shown and discussed in the ninth and final chapter.

CHAPTER 8 SHAPE PROGRAMS

In the small- and medium-network tests that were summarized in Chapter 5, FMC proved to be superior to THE and PC-LINKOD in estimating a trip table from link counts. However, FMC was designed to update an existing trip table to account for recent changes in the traffic flow pattern [Hamerslag and Immers], not to generate a new trip table solely from a network's flow pattern. Because (a) the objective of this project is to estimate a statewide O-D table for Indiana, based on the traffic volume counts on the state highway network, (b) Indiana has no previous trip table available to be updated, (c) FMC performed well in the tests of available O-D estimation methods, and (d) FMC is designed to be compatible with the TRANPLAN travel demand modeling software used by INDOT, the preferred strategy would be to find a practical and effective way to generate an appropriate initial trip table for FMC to "update".

In Section 1.2.3 of this report, three simple ways of creating a "seed" or initial trip table were described: observed, level, and O-D Factored. The latter two require no previous trip table. Other methods of generating an initial trip table from link counts only were investigated, including SHortest Augmenting Path Estimation (SHAPE) [Barbour and Fricker, 1994]. In this chapter, tests similar to those discussed in earlier chapters will be used to evaluate SHAPE.

Currently, there are two versions of SHAPE available -- SHAPE 2 and SHAPE 2+. SHAPE 2 finds the shortest path for every O-D pair, with ties between each O-D pair broken arbitrarily. Any overloaded link is reduced by the ratio (overload percentage) between the observed and the calculated link volumes. The flow on those links is sent back according to the corresponding overload percentages. The process is repeated until no overloaded links remain. The SHAPE 2 algorithm produces a trip table that, when loaded, does not exceed the observed traffic volumes. However, in some cases, some links may have loads that are far below in the observed volumes. The possibility of underloaded links prompted the SHAPE 2+ version of the program. In addition to checking for overloaded links, a module in SHAPE 2+ that assigns more trips to underloaded links has been added.

8.1 Things To Watch Out For

Programs to implement SHAPE were coded in FORTRAN. One input file is required for the program, which contains the network data with node connectivity and traffic information. Origin and destination zones must have separate node numbers, even though some nodes may actually serve as both origin and destination centroids. Nodes that are "unbalanced", i.e., that do not have inflow exactly equal to outflow, will be treated by the program as an origin or destination zone. A node with more entering trips than departing trips will be interpreted as a destination zone, even if this difference is only one trip. The additional zone numbers needed by SHAPE can be added. Because a balanced network is required by SHAPE programs, a balancing program coded by Daniel Beagan was used with the test networks [Beagan, 1986].

Four tables are produced for the two test networks using the two versions of SHAPE. They are listed in Tables 8.1-8.4.

8.2 Running FMC

The Gur730 and Village networks are again used to test FMC, but this time the SHAPE

Table 8.1 Gur 730 Network Initial Trip Table Produced by SHAPE 2

FROM/TO	1	2	3	4	5	6	TOTAL
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0
4	0	673	381	673	0	673	2400
5	500	3586	242	786	0	486	5600
6	0	541	378	541	0	541	2001
TOTAL	500	4800	1001	2000	0	1700	**10001**

Table 8.2 Gur 730 Network Initial Trip Table Produced by SHAPE 2+

FROM/TO	1	2	3	4	5	6	TOTAL
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0
4	0	1395	114	312	0	578	2399
5	500	2662	136	1181	0	1122	5601
6	0	743	750	507	0	0	2000
TOTAL	500	4800	1000	2000	0	1700	**10000**

results are used as the initial trip tables. Two elasticity settings are used for each initial trip table. (Refer to the FMC chapter of this report for more information on the elasticities.) The notation in parentheses indicates the elasticity values. For example, "z0s1" indicates zonal elasticity of "0" and screenline elasticity of "1". The calculated O-D tables are shown in Tables 8.5-8.8 and Tables 8.9-8.12, for the Gur 730 and Village networks, respectively.

8.3 Findings

The first inspection is made to determine how well the calculated results compare with known data. Tabulated results of production and attraction (P/A) and link-to-link (LTL) comparisons (see Section 2.5.2 for details) are shown in Tables 8.13 and 8.14. In both networks, the

Table 8.3 Village Network Initial Trip Table Produced by SHAPE 2

FROM/TO	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	TOTAL
1	123	0	15	13	13	20	4	310	40	284	14	7	2	7	13	865
2	15	11	18	18	15	1	5	4	11	18	6	7	2	2	17	150
3	133	13	216	28	15	3	5	4	141	63	14	42	2	7	25	711
4	5	5	30	28	15	3	5	3	16	17	12	7	0	8	20	174
5	5	5	97	55	15	4	5	3	16	17	12	7	0	8	32	281
6	97	5	21	3	2	4	1	4	22	105	14	7	0	3	2	290
7	20	5	70	12	10	3	5	4	121	12	14	7	0	7	11	301
8	13	0	13	13	13	15	4	66	40	63	14	7	2	7	13	283
9	62	6	412	5	4	7	5	4	321	120	14	9	2	5	32	1008
10	744	13	35	29	15	20	4	4	40	578	14	9	2	7	26	1540
11	11	5	11	4	3	3	5	4	11	11	8	7	2	3	11	99
12	41	13	32	3	2	14	4	4	38	45	14	8	2	7	25	252
13	37	6	45	5	4	5	5	4	45	44	14	8	0	4	29	255
14	53	5	37	21	8	4	5	4	18	65	13	7	0	8	10	258
15	5	5	26	25	15	3	5	3	16	17	12	7	0	8	19	166
TOTAL	1364	97	1078	262	149	109	67	425	896	1459	189	146	16	91	285	6633

Table 8.4 Village Network Initial Trip Table Produced by SHAPE 2+

FROM/TO	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	TOTAL
1	120	0	28	15	11	15	2	352	43	209	20	25	2	10	14	866
2	22	0	0	0	0	6	5	0	10	86	8	4	2	8	0	151
3	116	12	158	19	11	0	8	13	220	48	50	29	3	3	19	709
4	6	4	40	8	1	0	8	6	18	32	13	6	0	10	25	177
5	6	4	120	10	1	0	8	6	18	32	13	6	0	11	49	284
6	25	2	25	13	10	7	3	1	11	176	6	3	0	5	5	292
7	22	2	47	20	13	26	0	2	79	44	12	2	0	3	31	303
8	12	0	27	15	11	13	2	24	43	66	20	25	2	10	14	284
9	84	2	421	31	9	5	5	2	340	60	5	5	2	2	33	1006
10	852	0	44	27	15	15	2	5	43	456	20	23	2	10	25	1539
11	18	2	15	9	9	4	5	2	5	17	1	3	2	2	9	103
12	33	59	9	3	3	12	2	5	20	79	10	5	2	8	3	253
13	21	2	55	23	12	5	5	2	38	60	3	5	0	2	21	254
14	23	2	24	47	34	0	8	1	7	75	4	3	0	1	27	256
15	5	4	65	23	10	0	8	4	3	21	3	6	0	6	10	168
TOTAL	1365	95	1078	263	150	108	71	425	898	1461	188	150	17	91	285	6645

Table 8.5 O-D Table with the Gur 730 Network and SHAPE 2 Initial Matrix (z0s1)

FROM/T	1	2	3	4	5	6	TOTAL
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0
4	0	705	483	673	0	1235	3096
5	502	3457	160	1027	0	429	5575
6	0	701	319	984	0	541	2545
TOTAL	502	4863	962	2684	0	2205	**11216**

Table 8.6 O-D Table with the Gur 730 Network and SHAPE 2 Initial Matrix (z1s1)

FROM/T	1	2	3	4	5	6	TOTAL
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0
4	0	610	531	104	0	1210	2455
5	501	3508	176	987	0	416	5588
6	0	721	267	965	0	98	2051
TOTAL	501	4839	974	2056	0	1724	**10094**

Table 8.7 O-D Table with the Gur 730 Network and SHAPE 2+ Initial Matrix (z0s1)

FROM/T	1	2	3	4	5	6	TOTAL
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0
4	0	741	443	312	0	1245	2741
5	501	3135	131	1350	0	454	5571
6	0	984	386	667	0	0	2037
TOTAL	501	4860	960	2329	0	1699	**10349**

Table 8.8 O-D Table with the Gur 730 Network and SHAPE 2+ Initial Matrix (z1s1)

FROM/T	1	2	3	4	5	6	TOTAL
1	0	0	0	0	0	0	0
2	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0
4	0	677	479	32	0	1237	2425
5	501	3165	141	1329	0	448	5584
6	0	999	353	661	0	0	2013
TOTAL	501	4841	973	2022	0	1685	**10022**

Table 8.9 O-D Table with the Village Network and SHAPE 2 Initial Matrix (z0s1)

FROM/TO	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	TOTAL
1	123	0	5	24	20	22	2	379	48	340	15	18	1	10	32	1039
2	9	11	2	1	0	1	1	3	8	115	4	1	1	2	1	160
3	165	0	216	64	29	9	3	7	296	10	28	47	2	21	78	975
4	2	0	48	28	7	2	1	1	0	93	0	3	0	6	17	208
5	2	0	138	26	15	3	0	1	0	87	0	3	0	5	23	303
6	2	0	10	0	0	4	0	0	0	295	0	0	0	0	0	311
7	0	0	19	1	0	0	5	0	259	25	25	0	0	1	1	336
8	14	0	5	27	22	17	2	66	50	81	16	19	1	10	36	366
9	12	1	661	30	22	1	37	1	321	60	114	3	9	1	41	1314
10	1056	98	17	7	3	45	3	6	89	578	29	98	2	22	8	2061
11	1	1	13	15	10	0	16	1	27	4	8	1	4	0	10	111
12	7	4	1	16	10	2	0	1	8	200	2	8	0	1	0	260
13	6	1	53	17	13	1	14	1	102	17	27	2	0	1	27	282
14	1	0	58	11	3	3	1	0	0	174	0	0	0	8	8	267
15	3	0	65	24	12	4	1	2	25	1	17	4	0	11	19	188
																8181
TOTAL	1403	116	1311	291	166	114	86	469	1233	2080	285	207	20	99	301	8181

Table 8.10 O-D Table with the Village Network and SHAPE 2 Initial Matrix (z1s1)

FROM/TO	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	TOTAL
1	21	0	2	22	18	26	2	376	51	320	15	18	1	11	31	914
2	10	2	2	0	0	1	1	3	7	117	3	1	0	1	1	149
3	157	0	5	63	28	6	2	7	301	10	25	43	2	21	81	751
4	2	0	46	2	6	1	0	2	0	96	0	3	0	6	15	179
5	2	0	135	24	2	1	0	2	0	92	0	2	0	5	22	287
6	2	0	8	0	0	0	0	0	0	287	0	0	0	0	0	297
7	0	0	14	0	0	0	0	0	258	23	18	0	0	0	1	314
8	12	0	2	24	20	20	3	8	53	76	15	19	1	11	35	299
9	11	1	665	34	24	1	36	1	32	62	68	2	8	1	41	987
10	1071	92	17	7	3	49	3	7	86	44	24	80	2	22	8	1515
11	1	1	12	16	11	0	14	1	23	4	1	1	3	0	10	98
12	9	5	1	17	10	1	0	1	6	196	1	0	0	1	0	248
13	6	1	53	19	14	0	14	1	95	17	18	1	0	0	27	266
14	1	0	59	11	3	2	0	0	0	174	0	0	0	2	8	260
15	3	0	66	23	11	2	0	3	25	1	15	4	0	11	4	168
TOTAL	1308	102	1087	262	150	110	75	412	937	1519	203	174	17	92	284	6732

Table 8.11 O-D Table with the Village Network and SHAPE 2+ Initial Matrix (z0s1)

FROM/TO	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	TOTAL
1	120	0	9	28	22	22	1	373	50	310	18	30	1	11	39	1034
2	5	0	0	0	0	2	0	0	3	134	1	1	0	2	0	148
3	156	2	158	43	26	0	7	17	312	7	54	48	2	13	64	909
4	2	0	49	8	0	0	1	2	0	92	0	4	0	10	18	186
5	2	0	139	4	1	0	1	2	0	90	0	3	0	10	33	285
6	0	0	11	1	1	7	0	0	0	289	0	0	0	1	1	311
7	0	0	8	1	0	5	0	0	253	44	22	0	0	0	2	335
8	10	0	7	23	18	18	1	24	46	87	17	27	1	10	32	321
9	16	1	637	78	23	2	41	0	340	40	87	2	11	0	43	1321
10	1089	0	36	13	7	54	2	6	93	456	33	78	2	23	15	1907
11	2	1	15	12	12	1	13	0	25	6	1	1	4	0	7	100
12	2	83	0	4	5	2	0	0	4	165	1	5	0	1	0	272
13	3	1	52	29	15	1	11	0	124	23	6	1	0	0	17	283
14	0	0	28	19	14	0	1	0	0	179	0	0	0	1	18	260
15	3	0	116	16	7	0	2	2	3	1	2	5	0	10	10	177
TOTAL	1410	88	1265	279	151	114	81	426	1253	1923	242	205	21	92	299	7849

Table 8.12 O-D Table with the Village Network and SHAPE 2+ Initial Matrix (z1s1)

FROM/TO	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	TOTA
1	26	0	5	26	20	25	1	369	54	290	19	30	1	12	36	914
2	6	0	0	0	0	2	1	0	4	132	2	1	0	2	0	150
3	144	3	8	43	26	0	7	19	312	10	51	42	2	13	63	743
4	3	0	47	2	0	0	1	3	1	92	0	3	0	10	17	179
5	2	0	137	4	0	0	1	3	1	91	0	3	0	10	33	285
6	1	0	10	1	1	1	0	0	0	283	0	0	0	1	1	299
7	0	0	7	1	0	3	0	0	248	41	19	0	0	0	2	321
8	8	0	4	22	17	20	1	7	50	82	17	27	1	11	30	297
9	21	1	633	75	23	2	36	1	50	47	53	2	9	0	43	996
10	1094	0	40	14	8	53	2	7	89	78	29	62	2	21	17	1516
11	3	1	15	12	13	1	13	0	22	8	1	1	3	0	8	101
12	4	85	0	4	4	2	0	1	4	153	1	0	0	1	0	259
13	4	1	53	28	15	1	10	0	107	28	4	1	0	0	17	269
14	1	0	27	19	15	0	1	0	0	177	0	0	0	0	18	258
15	3	0	113	16	8	0	2	3	3	2	2	4	0	10	5	171
TOTAL	1320	91	1099	267	150	110	76	413	945	1514	198	176	18	91	290	6758

two initial trip tables did well in the P/A comparisons with a "z1s1" setting. This demonstrates that each SHAPE trip table result provided enough information to be considered a useful initial trip table for FMC. The LTL comparison is about the same with the two settings. This illustrates that FMC is capable of producing O-D tables while matching the observed traffic counts. This is consistent with the findings in Table 4.19: use a zonal elasticity setting of 1 when the initial trip table provides good travel pattern information.

Table 8.13 Initial Trip Table Comparisons

	Production and Attraction (%RMSE)	
Network	SHAPE 2	SHAPE 2+
Gur 730 Network (z0s1)	34.76%	13.62%
Gur 730 Network (z1s1)	3.057%	1.826%
Village Network (z0s1)	42.04%	34.14%
Village Network (z1s1)	5.104%	4.829%

Table 8.14 Link-To-Link Comparisons

	Link-To-Link Comparisons (%RMSE)	
Network	SHAPE 2	SHAPE 2+
Gur 730 Network (z0s1)	1.72%	2.22%
Gur 730 Network (z1s1)	1.71%	1.88%
Village Network (z0s1)	24.30%	24.54%
Village Network (z1s1)	24.53%	25.01%

In the next comparison, final calculated trip tables are compared with the known initial trip table. Table 8.15 has the tabulation of the results. Again, the "z1s1" results were better than the "z0s1" results.

Table 8.15 Initial Trip Table Comparisons

	Trip Table Comparison (%RMSE)	
Network	SHAPE 2	SHAPE 2+
Gur 730 Network (z0s1)	47.61%	58.64%
Gur 730 Network (z1s1)	37.71%	57.12%
Village Network (z0s1)	253.82%	239.51%
Village Network (z1s1)	197.71%	195.83%

The tendency of software to create or destroy trips is not desirable. Conservation of total system trips is a concept that should be important to O-D studies. From the above calculated O-D tables, the percentage differences of total number of trips and initial trip tables are summarized in Table 8.16.

Table 8.16 Total System Trips Comparison (Negative = Overestimate)

	% Difference Between System and Calculated Trips	
Network	SHAPE 2	SHAPE 2+
Gur 730 Network (z0s1)	-12.16%	-3.49%
Gur 730 Network (z1s1)	-0.94%	-0.22%
Village Network (z0s1)	-23.00%	-18.01%
Village Network (z1s1)	-1.218%	-1.609%

8.4 Conclusions

The SHAPE programs served as a good preprocessor to FMC for the Gur 730 and Village test networks. The trip tables produced by SHAPE programs did well in the goodness of fit comparisons and in the conservation of trips when the "z1s1" setting was used with FMC. However, the OD Factored trip table still produced slightly better results than those generated by the SHAPE programs. Neither version of the SHAPE program seems to work well with large and complex networks; two separate runs with both versions of SHAPE program took over 16 hours without any results, which led to the conclusion that the program is not suitable for large-sized networks. Modification of the SHAPE programs is required to improve the efficiency of the O-D calculation, either by working with the existing FORTRAN program or by using another language, such as C. Until such improvements in SHAPE can be implemented, the OD Factored trip table is recommended as the most practical way to generate an initial trip table that is suitable for use by FMC. This recommendation is carried out in the next chapter.

CHAPTER 9 CONCLUSIONS AND RECOMMENDATIONS

This chapter will furnish the results of variety of settings and initial matrices used with FMC to achieve the best O-D estimates in terms that were outlined in Chapter 5. This will include three initial trip tables, each with a range of zonal and screenline elasticity values. The results will be tabulated and one table will be recommended as the O-D matrix for the Indiana network based on P/A, LTL, and trip conservation comparisons. More important, the appropriate validation method and data requirements will be discussed for future application. As seen from the last two chapters, assumptions and estimations are made in order to proceed with the study. For further study more appropriate data would be required.

9.1 O-D Results with the Indiana Network

Three types of initial tables were used for the Indiana network: a level trip table, an OD Factored trip table, and a biased level trip table. The first two types of matrices had been discussed in Section 1.2.3. The third trip table attempts to match heavy through trips using two values in the level trip table. With this biased level trip table, the cells representing the external-external trips share the same value while the other cells (internal-internal, internal-external, and external-internal) are given another common value, generally a lower value, to reflect heavy through trips. The same program (SEEDTAB.EXE) that was used to generate traditional level trip tables is used to generate the biased level trip tables. This program would generate the file necessary for TranPlan to build a trip table for FMC.

The presentation of synthesized trip tables is separated into two sets by the number of iterations: 20 and 100 iterations. The FMC manual suggests trials with different elasticity settings. These two series accomplish the search for the optimum initial trip table and elasticity setting combination without excessive computation time [UAG, 1993]. Trip tables obtained with 20 iterations will illustrate potential settings for more detailed analyses with 100 iterations. P/A values are used for the goodness of fit test that is measured in term of %RMSE. For more information in regard to this measure, refer to Chapter 1.

The first comparison shows the result of three level trip tables. Three O-D calculations are performed with level trip cell values at 100, 260, and 1000. The value of 260 is obtained by dividing the total system trips by the number of cells. The other two values are used to determine the effect of using an overestimated and an underestimated initial trip table. The zonal and screenline elasticity values are 0 and 1, respectively. As shown in Table 9.1, the three initial trip tables produced similar results. These findings are consistent with the tests performed with the test networks in Chapter 4.

Table 9.1 Level Trip Table Comparison

Zonal Elasticity = 0, And Screenline Elasticity = 1	
Initial Trip Table Cell Value	Production and Attraction (%RMSE)
100	25.71%
260	25.65%
1000	25.61%

The second comparison involves the use of a level trip table while varying the zonal elasticity setting and keeping the screenline elasticity constant at 1. The results are summarized in Tables 9.2 and 9.3: Cell values of 260 and 100 are used for these comparisons. The best zonal elasticity setting when a level initial trip table is used is 0.0, as indicated in the tables. This means that a level trip table conveys and contributes little prior information for O-D calculations.

Table 9.2 Zonal Elasticity Comparison with Level Trip Table I

260 Cell Value, Screenline Elasticity = 1	
Zonal Elasticity	Production and Attraction (%RMSE)
0.00	25.65
0.25	40.18
0.50	49.50
0.75	56.02
1.00	60.77

Table 9.3 Zonal Elasticity Comparison with Level Trip Table II

100 Cell Value, Screenline Elasticity = 1	
Zonal Elasticity	Production and Attraction (%RMSE)
0.0	25.71
0.5	85.07
1.0	150.09

The next comparison involves the use of an OD Factored initial trip table. Two zonal elasticities and three screenline elasticities are used for the six calculations. The results are tabulated in Table 9.4. The elasticity setting designations are as follows: "z" stands for zonal elasticity and the number following it designates the elasticity value; a similar designation is used for the screenline elasticity. For example, "z0.0s0.25" stands for the setting using zonal elasticity of 0.0 and screenline elasticity of 0.25. The best settings (in terms of P/A comparisons) among those tried on the Indiana network are with zonal elasticity set at 1.0 and screenline elasticity set at 1.0.

Table 9.4 O-D Factored Initial Trip Table Comparison

Zonal/Screenline Elasticity Setting	Production and Attraction (%RMSE)
z0.0s0.25	64.18
z0.0s0.70	30.30
z0.0s1.00	24.79
z1.0s0.25	16.19
z1.0s0.70	15.67
z1.0s1.00	15.39

Shown in Table 9.5 is the comparison of biased level trip tables, which are different internal-internal and external-external cell values that are used in an attempt to direct the O-D calculation to reflect more through trips, as is the case with the Indiana network. The combination with the least amount of error in terms of P/A values is the first set, using a cell value of 1000 for external-external zones and 100 for the rest. The zonal and screenline elasticity values are kept constant for this comparison at 0 and 1, respectively.

Table 9.5 Biased Level Trip Comparison

I-I /X-X Level Trip Table Cell Value	Production and Attraction (%RMSE)
100/1000z0s1	26.73
100/10000z0s1	34.00
1000/10000z0s1	27.18

The final tabulation includes the initial trip tables that produced promising results in Tables 9.1-9.5. Table 9.6 shows the performance of 100 iterations with additional measures of goodness of fit. Column Two is the same comparison as in other tables: the comparison of zonal production and attraction values. Column Three is the comparison of total trips in the system compared with the observed volume; values are reported in percentage difference between the observed and calculated values. A positive value means the observed value is greater than calculated value, meaning an underestimation as the result of the process. In the fourth column are the %RMSE values for the screenlines used in the O-D calculations. These are the links FMC used in matching traffic counts. The last column is the sum of the screenline traffic volumes, reported in percentage between observed and calculated screenlines. A negative value in this column means that the total trip volume is overestimated. From the tabulation in Table 9.6, the performances of the three level trip tables appear to be very similar, no matter what initial cell values were used. The OD Factored initial trip table, however, proved to have better a fit by comparison, which is consistent with the findings in Chapter 4.

Table 9.6 Comparisons of Initial Trip Tables for Indiana Network, 100 Iterations

Initial Trip Table	Production and Attraction (%RMSE)	System Trips (3,474,913 Trips) (%Difference)*	Screenline (%RMSE)	Screenline Trips (9,362,636 Trips) (%Difference)*
lv100z0s1	17.43	1.90%	23.86	3.73E-2%
lv260z0s1	17.41	1.89%	23.85	3.59E-2%
100/1000z0s1	17.45	1.90%	23.88	3.43E-2%
odfactoredz0s1	17.46	1.91%	23.90	3.76E-2%
odfactoredz1s1	11.34	1.28%	21.26	-0.94%

*Negative = Overestimate

9.2 Recommended O-D Tables

The five calculated O-D tables share the same characteristic: many zone pairs have severely underestimated total trips, especially the external-external zone pairs. Many through trips are instead attracted to the nearest counties or gateways. The problem reveals FMC's of great sensitivity to the choice of screenline locations. For example, the number of trips for O-D pairs 101-110 and 101-109 are 1 and 19, respectively, for the "odfactoredz1s1" setting seen in Table 9.6. These two zone pairs represent the through trips from Louisville to Chicago. The calculation was done by using the ASSEVA file discussed in Section 7.2. The same O-D calculation with fewer screenlines on I-65, which is the major route connecting zone pairs 101-110 and 101-109, produced trip values of 0 and 2 for these zone pairs. The decrease in trip values are due to the attraction power of the remaining screenlines. In order to address this sensitivity to screenline locations and achieve a more reasonable flow pattern, two actions can be taken: use more screenlines to better distribute the trips or use a minimum number of screenlines so as to not distort the observed traffic flow patterns. FMC with the first method (more screenlines) was used on the two test networks and achieved results superior to the other two software packages. Because of the 450-screenline limit, however, the first method cannot be used on the Indiana network. FMC with the second method (minimum screenlines) will produce a more reasonable O-D table when compared with the five matrices in Table 9.6. The results from the minimum screenlines method will depend on the quality of the initial trip table. The OD Factored trip table is used in this case, because it provided good initial information when used with FMC in earlier tests. Refer to Chapter 4 for more information and test results from the use of an OD Factored initial table. Using the second method (minimum screenlines), trip values of 595 and 1804 are calculated for zone pairs 101-110 and 101-109, respectively. However, these values are changed drastically with addition of a few screenlines on I-65. Trips between zone pairs are reduced to 4 and 13 for the same zone pairs. This illustrates the sensitivity of screenline choices. The error results of the recommended O-D table are shown in Table 9.7 and the table can be seen in the Appendix.

Table 9.7 Recommended O-D Table

Initial Trip Table	Production and Attraction (%RMSE)	System Trips (3,474,913 Trips) (%Difference)	Screenline %RMSE	Screenline Trips (6,949,230 Trips) (%Difference)
odfactoredz1s1	9.69	3.21%	9.70	-3.22%

9.3 Conclusions and Further Study

This study was conducted in a way that updated information can be readily incorporated into the O-D calculation as they become available through the use of computer programs developed for the project. The most important improvement will be the availability of updated and suitable information. For starters, an actual O-D study would be the best means of validating any O-D table estimates from link counts for this network, regardless of the methods or programs used. An actual O-D study with traditional survey methods would be most valuable, because it serves two purposes: a starting point and a means to validate the process. Without a large scale O-D study, a spot-check study can be incorporated on various gateways and county borders. The results from these spot-check studies can be used with FMC through the use of the optional flag matrix to preserve these values during the computation process. The implementation of the computer package will continue the O-D estimation and updating process once the procedure is verified. The three packages evaluated in the study are designed for updating matrices and not for synthesizing new O-D matrices only from traffic counts. However, the packages are capable of synthesizing matrices given reasonable information. Having a traffic flow pattern is especially important in a large network with heavy through traffic. One possible resolution besides a large scale statewide study would be to determine only the external-external traffic flows and use the optional flag matrix in FMC to fix those cells. This would reduce the survey effort from 115 zones to only 23 gateways.

Other information that would be helpful is the actual production and attraction values. These values are important to the study because they dictate the amount of trips to be loaded onto the network. With this study, estimates of production and attraction values were made by summing traffic volumes that went across county lines. A 50/50 directional split was assumed. Detailed analysis is required to determine the optimum location for centroids and their connectors. This would more realistically portray travel patterns by loading the network in appropriate locations. In the study, link volumes are extracted from INDOT's highway statistics publication and stored in TransCAD, which can be used for other statewide studies in addition to the O-D study. However, a directional split is necessary to provide accurate traffic flow information. Based on the experiences acquired in this study, Figure 9.1 illustrates the hierarchy of the information needed for an accurate and valid O-D calculation.

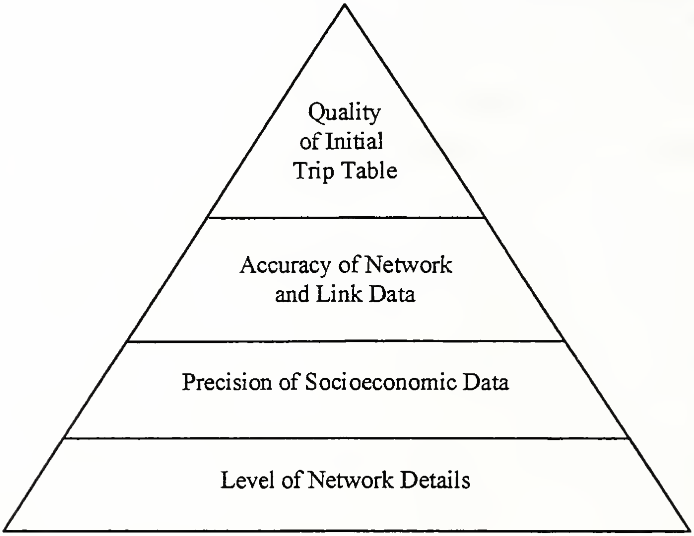

Figure 9.1 O-D Estimation Information Hierarchy

The level of network detail is not critical, as long as there are paths leading from and to every zone and gateway. The next most important information is the socioeconomic data; zonal production and attraction values are required to be loaded onto the network. Estimation by using traffic counts is done in lieu of production and attraction information. Accuracy of the network is critical in performing O-D calculations. This includes the correct coding information, such as links, nodes, and traffic data. Lastly, the most important information would be an initial trip table, one that would provide additional information for synthesizing an O-D matrix, such as traffic flow pattern, outdated or otherwise. The initial trip table can provide partial O-D information, with the use of the flag matrix and zonal elasticities in FMC, this information can be used to its full potential.

One problem with FMC is the 450 limit on screenlines that can be used in the O-D calculation. As described earlier in this chapter, oversensitivity to screenline choices can occur when a subset of network links are used as screenlines. Although reasonable counts exist for the 2312 one-way links that make up the Indiana network, the FMC limit on screenlines does not permit us to use all available information. In order to preserve the observed flow pattern, more screenlines would be required.

The TranPlan/FMC combination provides the capabilities needed to estimate an O-D table for the Indiana network from counts at key locations on the network. The combination is also practical to use, once all the necessary files are constructed. The modular design is easy to use with a little experience. It also makes the debugging of the files easier, using the output files that are generated by every module.

The study has laid out the basis for using the new data described above, once they become available. The programs written for the study will greatly reduce the data processing and preparation time. The programs include conversion of the database from TransCAD to TranPlan format and to build files for FMC. The study concludes here with the most recent and the best available data. This study will serve as a valuable guide to continue the O-D study in a statewide network, as FMC's screenline limitation is increased and as updated information become available. FMC is an appropriate package to use, given its flexibilities and capabilities.

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IMPLEMENTATION SUGGESTIONS

This project has produced a trip table for the Indiana state highway network, based on Annual Average Daily Traffic (AADT) data collected by the Indiana Department of Transportation. As the AADT values change, a new statewide trip table can be estimated.

The required elements of the procedure to produce such a new estimate are:

A. A current version of the TRANPLAN travel demand modeling software package.

B. A TRANPLAN file that contains productions (or total origins) and attractions (or total destinations) for each zone in the network.

C. A file (in TRANPLAN format) that contains a description of the Indiana state highway network.

D. The FORTRAN program "od.f", or any program that converts productions (or origins) and attractions (or destinations) into an "O-D Factored" trip table. (See Section 1.2.3 of this report for a description of the O-D Factored trip table.)

E. The TRANPLAN function "FMC", which is used to "update" the O-D Factored trip table.

The following steps will lead to an estimated statewide trip table.

1. Update the link list (in TRANPLAN format) to reflect any changes in AADT values.
2. Prepare a TRANPLAN batch file to build the Indiana network, using Section 6.2.4 of this report as a guide.
3. Prepare additional TRANPLAN batch files in accordance with the detailed guidance given in Sections 7.1-7.3 of this report.
4. Prepare a batch file to run FMC. See Section 7.4.

5. Run the FORTAN program "od.f" to produce an O-D Factored trip table to serve as the input trip table for FMC.

Run TRANPLAN with the FMC function to produce an estimated statewide trip table.

APPENDIX

PROMTO	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33
1	0	261	166	24	10	176	33	61	64	392	136	143	62	39	176	80	114	164	42	219	30	246	65	18	44	77	129	46	345	190	87	311	162
2	261	0	1067	132	63	982	181	277	284	2147	742	780	292	209	966	440	626	845	228	1191	169	1357	357	101	237	419	703	247	1986	1041	474	1704	988
3	166	1067	0	102	41	702	141	216	228	1666	676	606	219	162	749	342	485	856	176	924	131	1053	277	79	184	326	646	181	1464	808	389	1323	880
4	24	132	102	0	6	94	17	26	28	206	71	76	27	20	82	43	60	81	22	116	16	130	34	10	22	41	68	23	180	99	46	163	65
5	10	63	41	6	0	38	7	10	11	82	29	30	11	9	38	17	24	32	9	46	6	62	13	4	9	16	27	9	72	40	19	65	34
6	176	982	702	94	38	0	130	188	210	1632	630	657	201	149	689	314	447	603	162	850	120	868	254	73	169	299	602	176	1346	743	338	1216	633
7	33	191	141	17	7	130	0	36	39	293	98	103	37	27	128	58	83	111	30	157	22	176	47	13	31	66	93	32	248	137	83	225	118
8	61	277	216	26	10	188	36	0	60	432	149	167	67	42	185	88	126	170	46	239	33	273	72	20	48	84	142	60	379	210	95	343	178
9	64	284	228	28	11	210	39	60	0	459	169	167	60	46	207	94	134	180	49	254	36	290	76	21	61	89	160	63	403	222	101	364	190
10	392	2147	1667	206	82	1632	293	432	459	0	1166	1216	439	326	1506	680	877	1310	355	1858	262	2117	656	169	370	654	1098	385	2043	1624	740	2660	1386
11	136	742	670	71	29	630	99	149	169	1158	0	422	162	112	621	237	337	468	123	643	90	732	193	65	128	228	379	133	1017	661	265	819	478
12	143	780	606	76	30	667	103	167	167	1216	422	0	160	119	648	249	366	479	129	878	95	770	203	69	135	239	389	140	1070	691	270	987	604
13	62	292	219	27	11	201	37	67	60	439	162	160	0	43	198	90	128	173	47	243	34	278	73	21	49	88	144	61	386	213	97	349	181
14	39	209	162	20	9	149	27	42	46	325	112	119	43	0	147	67	95	129	34	180	25	206	64	16	36	64	106	37	286	156	72	258	135
15	176	965	740	92	38	689	128	195	207	1506	621	648	198	146	0	308	440	693	160	936	118	852	260	71	166	294	484	173	1323	731	332	1190	823
16	80	440	342	43	17	314	68	88	94	686	237	249	90	67	308	0	200	271	73	381	64	434	113	32	76	134	226	79	603	337	162	644	284
17	114	626	485	60	24	447	83	126	134	977	337	356	128	95	440	200	0	386	103	642	78	617	162	47	109	190	320	112	856	473	216	776	404
18	164	846	860	81	32	603	111	170	180	1319	456	479	173	129	693	271	386	0	140	732	103	833	219	63	146	257	432	157	1169	640	291	1047	645
19	42	228	170	22	9	162	30	46	49	355	123	129	47	34	160	73	103	140	0	197	27	226	69	17	40	69	117	41	312	172	79	282	147
20	216	1191	924	116	46	850	167	239	254	1858	643	876	243	180	830	381	642	732	197	0	146	1176	309	88	206	363	609	214	1632	901	410	1476	769
21	30	169	131	16	6	120	22	33	35	262	90	95	34	26	119	64	78	103	27	145	0	165	44	12	29	61	68	30	230	127	68	208	108
22	246	1357	1063	130	62	868	178	273	290	2117	732	770	278	206	852	434	617	834	226	1176	165	0	352	100	234	413	693	243	1880	1027	467	1681	976
23	65	357	277	34	13	254	47	72	76	657	193	203	73	64	250	113	162	219	69	309	44	352	0	26	62	109	182	64	489	270	123	442	230
24	18	101	79	10	4	73	13	20	21	169	65	68	21	16	71	32	47	63	17	88	12	100	26	0	17	31	57	19	139	77	35	176	66
25	44	237	184	22	9	169	31	48	61	370	128	136	49	36	166	76	108	146	40	208	29	234	62	17	0	72	122	43	326	179	82	294	153
26	77	419	325	41	16	299	66	84	89	654	228	239	88	64	294	134	190	257	69	383	61	414	109	31	72	0	214	76	676	317	145	619	271
27	129	703	646	68	27	602	93	142	160	1097	379	389	144	106	493	226	320	432	117	609	68	693	182	62	122	214	0	127	964	632	242	972	454
28	46	247	181	23	9	176	32	60	63	385	133	140	61	37	173	79	112	162	41	214	30	243	64	19	43	76	127	0	338	186	85	308	168
29	345	1986	1464	180	72	1346	248	379	403	2943	1018	1070	386	286	1324	603	858	1169	312	1633	230	1860	489	139	326	676	964	338	0	1427	650	2336	1217
30	191	1041	808	99	40	743	137	210	222	1623	661	691	213	169	731	332	473	638	172	901	127	1027	270	77	179	317	632	186	1426	0	369	1299	672
31	87	474	369	40	19	338	83	95	101	740	255	270	97	72	332	162	216	291	79	410	68	467	123	35	82	146	242	85	650	359	0	687	306
32	311	1704	1323	163	66	1216	225	343	364	2659	819	987	349	258	1166	644	776	1047	282	1478	208	1681	442	128	294	619	972	308	2336	1299	588	0	1100
33	162	889	669	65	34	633	118	178	190	1386	479	604	181	136	623	284	404	645	147	769	108	870	230	66	153	271	454	169	1219	672	308	1100	0
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35	120	657	610	63	25	469	86	132	140	1024	354	373	135	98	461	210	299	403	109	669	80	848	170	49	113	200	335	116	900	497	226	813	424
36	145	784	616	76	30	666	104	169	169	1238	428	450	182	121	658	253	381	487	132	687	96	782	206	69	137	241	405	142	1088	600	274	882	612
37	131	713	653	68	27	600	84	144	162	1112	384	404	146	106	601	229	324	438	119	617	87	703	184	63	123	217	365	128	977	639	245	883	460
38	35	197	162	16	7	140	20	40	47	308	105	111	41	29	138	63	89	121	32	170	24	194	61	14	33	60	100	35	269	148	68	243	127
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40	46	246	182	23	9	176	32	60	63	385	133	140	61	37	173	79	112	162	41	214	30	243	64	19	43	76	126	45	339	186	85	305	159
41	284	1552	1204	149	60	1107	205	312	331	2420	837	881	317	235	1089	498	708	954	256	1343	190	1631	402	115	269	472	784	279	2127	1174	635	1922	1001
42	67	303	282	34	14	269	48	73	78	667	198	206	74	65	265	117	165	223	60	314	45	359	84	20	63	110	185	65	498	275	126	450	234
43	69	370	297	35	14	283	49	74	79	677	200	210	76	66	259	119	169	227	61	320	46	365	86	27	84	112	188	66	607	280	129	459	239
44	104	672	444	66	22	408	76	116	123	892	308	324	117	97	401	192	260	352	94	496	70	563	149	43	88	174	283	102	784	433	198	708	369
45	597	3213	2484	308	124	2293	424	647	697	6014	1734	1874	668	488	2256	1027	1463	1975	532	2792	392	3170	833	237	555	976	1543	377	4406	2431	1108	3981	2074
46	383	1984	1540	191	78	1416	261	399	424	3096	1070	1126	406	301	1393	634	603	1216	328	1719	242	1957	614	147	343	604	1015	356	2721	1601	684	2469	1281
47	65	300	232	28	11	214	40	60	64	487	181	170	61	46	210	90	137	184	60	259	36	286	78	22	62	61	163	54	411	227	103	371	184
48	209	1141	888	109	44	916	151	230	244	1791	616	646	233	173	801	365	620	701	189	989	139	1126	296	84	197	348	684	205	1565	983	393	1414	737
49	1037	6672	4402	644	217	4047	748	1141	1213	8849	3059	3218	1160	960	3979	1813	2581	3484	839	4909	682	6594	1470	419	978	1728	2900	1017	7774	4280	1955	7025	3881
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20	35	23	8	26	22	7	165	61	38	34	10	8	13	69	8264
22	38	26	8	27	25	7	173	57	44	38	11	11	14	70	10363
166	290	192	62	205	186	64	1298	432	330	288	83	81	108	71	78082
70	123	81	26	87	78	23	548	182	138	121	35	34	44	72	32581
74	130	86	28	91	83	24	580	192	147	129	37	36	47	73	34308
64	95	62	20	66	60	17	423	140	108	84	27	26	34	74	25164
43	76	60	16	54	48	14	340	113	88	76	22	21	28	75	20284
77	136	90	29	96	87	25	607	202	166	135	39	37	49	76	38037
32	67	37	12	40	37	10	265	85	65	66	16	16	20	77	16222
3	4	3	1	3	3	1	19	7	6	4	1	1	2	78	1161
107	187	124	40	132	116	34	837	278	213	185	54	62	68	79	48471
48	83	55	16	59	63	16	371	123	84	82	24	23	30	80	22074
14	26	17	6	18	16	5	116	38	28	26	8	7	6	81	6843
168	276	183	60	195	176	61	1238	411	313	274	78	77	100	82	72608
43	76	60	16	64	48	14	339	113	88	76	21	21	27	83	20204
103	160	119	38	128	116	33	807	268	205	178	52	50	66	84	47687
27	48	32	10	34	31	9	216	71	66	48	14	14	18	85	12877
27	47	32	10	33	30	9	211	70	64	47	14	13	17	86	12598
89	172	114	37	122	111	31	773	257	186	172	49	48	63	87	45725
20	36	24	8	26	23	7	160	53	41	36	10	10	13	88	8562
81	141	84	31	100	90	26	630	210	160	140	40	39	61	89	37390
23	40	26	9	29	26	8	181	60	46	40	12	11	14	90	10807
87	152	101	32	107	97	28	681	226	172	161	43	43	56	91	40308
76	132	88	28	94	84	26	583	187	150	131	38	37	48	92	35184
268	474	310	99	332	303	85	2123	702	538	467	134	134	169	93	21004
58	88	63	21	70	63	21	439	146	112	98	28	29	36	94	4416
146	261	169	56	183	169	49	1160	388	286	254	77	70	81	95	11638
70	120	77	28	84	77	21	647	183	141	120	35	35	42	96	6484
89	169	112	35	120	105	29	755	247	190	169	40	40	53	97	7689
410	716	474	165	610	460	134	3215	1066	816	709	205	188	261	98	31490
604	1046	696	227	730	668	191	4704	1562	1199	1030	298	281	383	99	46310
84	149	98	29	105	91	29	656	219	169	148	42	42	56	100	6581
233	403	268	84	282	254	77	1804	695	460	396	113	113	148	101	17901
0	276	183	58	190	176	49	1226	410	311	268	77	77	98	102	12270
276	0	317	106	339	303	85	2145	709	645	474	134	134	176	103	21240
183	317	0	70	226	204	68	1420	474	360	310	91	91	113	104	14182
66	106	70	0	70	63	21	460	165	120	89	28	28	35	105	4830
190	339	225	70	0	218	63	1615	602	381	332	98	91	120	106	16107
176	303	204	63	218	0	66	1370	463	346	304	84	84	113	107	13676
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1226	2145	1420	460	1516	1370	306	0	3103	2436	2124	612	607	778	109	87677
410	709	474	165	602	453	134	3103	0	808	709	205	188	261	110	31280
311	645	360	120	381	346	88	2436	808	0	536	165	148	187	111	24083
268	474	310	99	332	304	85	2124	706	638	0	134	134	169	112	21043
77	134	91	28	98	84	28	612	205	165	134	0	35	49	113	6167
77	134	91	28	91	84	21	607	188	148	134	35	0	49	114	6003
98	176	113	36	120	113	35	778	261	187	169	46	46	0	115	7827
102	103	104	105	106	107	108	109	110	111	112	113	114	115	TO/FROM	
12272	21244	14184	4631	15110	13677	3895	87692	31287	24066	21047	6169	6004	7830		3586720

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